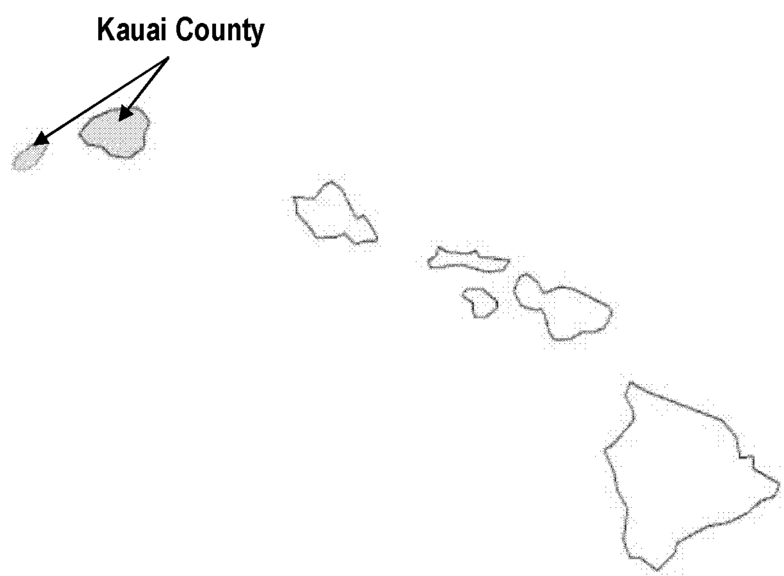
FLOOD INSURANCE STUDY

VOLUME 1 OF 2



KAUAI COUNTY, HAWAII

REVISED:
NOVEMBER 26, 2010

Federal Emergency Management Agency

COMMUNITY NUMBER-150002V001C

NOTICE TO
FLOOD INSURANCE STUDY USERS

Communities participating in the National Flood Insurance Program have established repositories of flood hazard data for floodplain management and flood insurance purposes. This Flood Insurance Study (FIS) may not contain all data available within the repository. It is advisable to contact the community repository for any additional data.

Part or all of this FIS may be revised and republished at any time. In addition, part of this FIS may be revised by the Letter of Map Revision process, which does not involve republication or redistribution of the FIS. It is, therefore, the responsibility of the user to consult with community officials and to check the community repository to obtain the most current FIS components. This publication incorporates revisions to the original FIS.

Effective Date:	November 4, 1981
Revised Dates:	March 4, 1987- To change floodplain boundaries, zone designations, base flood elevations, corporate limits, scale, cultural features, and map format.
	September 30, 1995- To change base flood elevation, to add special flood hazard areas, to change special flood hazard areas, to change zone designation, to add roads and road names, to incorporate previously issued letter of map revision.
	October 18, 2002- To change base flood elevations and to change floodway.
	September 16, 2005- To update base map information.
	November 26, 2010- To change base flood elevation, to add special flood hazard areas, to change special flood hazard areas, to change zone designation, and to incorporate previously issued letter of map revision.

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FLOOD INSURANCE STUDY
KAUAI COUNTY, HAWAII

1.0 INTRODUCTION

1.1 Purpose of Study

This Flood Insurance Study (FIS) revises and updates information on the existence and severity of flood hazards in the geographic area of Kauai County, Hawaii, and aids in the administration of the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973. This study has developed flood-risk data for various areas of the community that will be used to establish actuarial flood insurance rates and to assist the community in its efforts to promote sound floodplain management. Minimum floodplain management requirements for participation in the National Flood Insurance Program (NFIP) are set forth in the Code of Federal Regulations at 44 CFR, 60.3.

In some States or communities, floodplain management criteria or regulations may exist that are more restrictive or comprehensive than the minimum Federal requirements. In such cases, the more restrictive criteria take precedence and the State (or other jurisdictional agency) will be able to explain them.

The Digital Flood Insurance Rate Map (DFIRM) and FIS report for this countywide study have been produced in digital format. Flood hazard information was converted to meet the Federal Emergency Management Agency (FEMA) DFIRM database specifications and Geographic Information System (GIS) format requirements. The flood hazard information was created and is provided in a digital format so that it can be incorporated into a local GIS and be accessed more easily by the community.

1.2 Authority and Acknowledgments

The sources of authority for this FIS are the National Flood Insurance Act of 1968 and the Flood Disaster Protection Act of 1973.

For the original FIS, the hydrologic and hydraulic analyses were prepared by the U.S. Army Corps of Engineers (CEO), Pacific Ocean Division for the Federal Emergency Management Agency (FEMA), under Inter-Agency Agreement Nos. IAA-H-7-76 and IAA-H-10-77, Project Nos. 26 and 4. That work was completed in June 1978.

The March 4, 1987 revision of the hydrologic and hydraulic analyses for Wainiha River, Opaekaa Stream, Opaekaa Tributary, Huleia Stream, Papakolea Stream, Lawai Stream, Lawai Stream Side Channel, Waimea River, and Kekaha Drainageway were prepared by the COE for FEMA, under Inter-Agency

Agreements EMW-84-E-1506, project Order No. 1, Amendment No. 2. This work was completed in June 1985.

The September 30, 1995, revision of the hydrologic and hydraulic analyses for Hanamaulu Stream, Kalama Stream, and Waikomo Stream was prepared by Sam O. Hirota, Inc. (SHI), under Contract No. EMW-89-C-2842. This revision incorporated previously issued LOMRs. This revision also incorporates new detailed flooding information along the coast of the Island of Kauai between Kekaha and Poipu. The data for this portion of the restudy were prepared by U.S. Army Corps of Engineers (USACE), Pacific Division, under Contract no. EMW-93-E-4119.

The October 18, 2002, revision of the hydrologic and hydraulic analyses for Hanalei River was prepared by the U.S. Army Corps of Engineers (USACE), Honolulu District, for FEMA under Interagency Agreement No. EMW-96-IA0288.

The September 16, 2005, revision updated the base map information shown on the FIRM derived from mosaicked 2-foot resolution satellite imagery that meets 1:12,000 scale horizontal accuracy standards. This information was collected between July 2002 and January 2004.

The November 26, 2010 revision of new detailed coastal hurricane storm surge and wave height analysis and approximate analyses of "behind levee" flooding were prepared, in March 2008, by RMTC/URS, a JV, under FEMA contract number EMW-2003-CO-0046.

Methodology for the digital conversion of the effective FIRM involved georeferencing raster images of the most recent FIRMs to the new base map, then on-screen digitizing and labeling of hydrologic, hydraulic, physiographic, and political features using ESRI ArcMap 8.3 and 9.0.

1.3 Coordination

Consultation Coordination Officer's (CCO) meetings may be held for the community. An initial CCO meeting is held typically with representatives of FEMA, the community, and the study contractor to explain the nature and purpose of a FIS, and to identify the streams to be studied by detailed methods. A final CCO meeting is held typically with representatives of FEMA, the community, and the study contractor to review the results of the study.

The dates of the initial and final CCO meetings held for Kauai County and the incorporated communities within its boundaries are shown in Table 1, "Initial and Final CCO Meetings."

TABLE 1 – INITIAL AND FINAL CCO MEETINGS

For FIS Dated	Initial	Intermediate	Final
November 4, 1981	March 1976	February 23, 1977 March 1, 1978	May 14 &15, 1980
March 4, 1987	August 1983	*	*
September 30, 1995	*	*	*
October 18, 2002	*	*	November 8, 2001
September 16, 2005	*	*	December 2004
November 26, 2010	*	*	August 25, 2009

*Data not available

2.0 AREA STUDIED

2.1 Scope of Study

This FIS covers the community of Kauai County, Hawaii.

The Island of Niihau is privately owned and therefore, it was not included in this study. In addition, the Islands of Lehua and Kaula were not studied.

All or portions of the flooding sources listed in Table 2, "Flooding Sources Studied by Detailed Methods," were studied by detailed methods.

TABLE 2 – FLOODING SOURCES STUDIED BY DETAILED METHODS

Hanalei Watershed
Waipa Stream
Waioli Stream
Hanalei River

Kapaa Watershed
Kapaa Stream
Moikeha Canal
Waikaea Canal

West Kauai Watershed
Kekaha Drainageway

Waimea Watershed
Waimea River

Wailua Watershed
Wailua River
Opaekaa Stream
Opaekaa Tributary
Kalama Stream

Lihue Watershed
Nawiliwili Stream
Puali Stream
Huleia Stream
Papakolea Stream

Hanapepe Watershed
Hanapepe River

Other Areas
Hanamaulu Stream

Anahola Watershed
Anahola Stream

Koloa Watershed
Waikomo Stream
Omao Stream
Lawai Stream

Wainiha Watershed
Wainiha River

Tsunami inundation on the entire coastline of the Island of Kauai was studied by detailed methods. The methodology employed to delineate inundation limits of tsunami of the selected recurrence intervals was agreed on at a tsunami conference held on February 23, 1977. The southwestern coastline of the island of Kauai was initially restudied to account for the severe coastal inundation caused by Hurricane Iwa in 1982. The southwest, south, and eastern coastlines were restudied in 2008 to include hurricane storm surge and wave height hazards using detailed methods. The detailed study extends from Nohili Point to Kuaehu Point in the 2010 restudy. No new analysis was performed along the northern coastline.

Limits of detailed study are indicated on the Flood Profiles (Exhibit 1). The areas studied by detailed methods were selected with priority given to all known flood hazard areas and areas of projected development and proposed construction.

All or portions of the flooding sources listed in Table 3, "Flooding Sources Studied by Approximate Methods," were studied by approximate methods:

TABLE 3 – FLOODING SOURCES STUDIED BY APPROXIMATE METHODS

Wainiha Watershed
Limahui Stream
Lumahai River
Manoa Stream
Wainiha River

Lihue Watershed
Kealia Stream

Kapaa Watershed
Keailia Stream

Hanalei Watershed
Hanalei River
Stream No. 1

Koloa Watershed
Waihohonu Stream

Wailua Watershed
Lower Reach of Opaekaa Stream

Kalihiwai Watershed
Kalihiwai River
Kilauea Stream
Moloaa Stream
Papaa Stream

Waimea Watershed
Waimea River
Makaweli River

Approximate analyses were used to study those areas having a low development potential or minimal flood hazards. The scope and methods of study were proposed to, and agreed upon by, FEMA and Kauai County.

This FIS also incorporates the determinations of letters issued by FEMA resulting in map changes (Letter of Map Revision – LOMR), as shown in Table 4, "Letters of Map Change."

TABLE 4 – LETTERS OF MAP CHANGE

Case Number	Project Identifier	Effective Date	Type
07-09-0537P	Floodplain boundaries and zone designations were modified along the coast of the Pacific Ocean	January 26, 2007	LOMR
03-09-0017P	Floodplain boundaries and zone designations were modified at Haena Point	October 21, 2002	LOMR
199210607MBJ	Floodplain boundaries and zone designations were modified along the coast of the Pacific Ocean	June 9, 1988	LOMR
199105419FIA	Incorporated information shown on July 1984 topographic map	April 6, 1987	LOMR
199210608MBJ	Floodplain boundaries and zone designations were modified along the coast of the Pacific Ocean	August 7, 1986	LOMR

2.2 Community Description

The State of Hawaii legally consists of 132 islands with a total land area of 6,425 square miles; however, approximately 99.9% of the area (6,421.6 square miles) is contained within eight major islands. These islands, their land area, and their jurisdictional counties are as follows:

Island	**Land Area (square miles)**	**County**
Hawaii	4,037.0	Hawaii
Maui	728.2	Maui
Oahu	592.7	Honolulu
Kauai	548.7	Kauai
Molokai	260.9	Maui
Lanai	139.5	Maui
Niihau (Privately Owned)	69.6	Kauai
Kahoolawe	45.0	Maui
Lehua	0.7	Kauai

Hawaii is unique in the United States in that it only has two levels of government: state and county. There are no smaller municipalities under the county, and no school districts.

Kauai County is comprised of the Islands of Kauai, Niihau, and Lehua. As mentioned in Section 2.1, Niihau is a privately owned island and was not included in this study.
The Island of Kauai lies northwest of the major Hawaiian island, and is roughly oval, measuring approximately 32 miles in width and 25 miles in length. The island's highest elevation, 5,423 feet, is at the summit of Mount Waialeale.

The Island of Kauai enjoys a tropical climate of warm temperatures, with moderate humidity and gentle tradewinds. Generally, the climate is favorable year-round, with average temperatures near the coast of 71° F in February and March, and 79°F in August and September. Temperatures are cooler in the mountains. Moist, northeasterly tradewinds prevail 50 to 60 percent of the time and normally supply the island with an abundance of rainfall, especially in the central and windward areas. Mount Waialeale, standing in the center of the island, receives the world's highest recorded average of annual rainfall of 480 inches.

The geology of the island is complex. Volcanic activity formed the islands of Hawaii. Originally, the Island of Kauai was a circular volcanic dome. A series of collapses, faulting, erosion, volcanic action, and deep weathering has transformed it original surface. The Mana coastal and the upper westward-sloping ridges are the only areas that approximate the original surface of the dome.

In the past, the island has been battered by hurricanes, tropical storms, high waves, and tsunami. On January 24 and 25, 1956, an extraordinary storm was centered over the Kilauea area, located in the Kalihiwai Watershed. Nearly 40 inches of rain were recorded within a 24-hour period by a gage on the Kilauea Plantation. Of that amount, 6 inches fell with a 30-minute period (USACE, 1968).

The population of Kauai is estimated to be 63,689 (U.S. Department of Commerce, 2010). The economy of Kauai is based on the agriculture, primarily sugar production. However, tourism has increased in recent years and is expected to contribute a greater amount to the island's economy in the future. Descriptions of the areas studied by detailed methods follow.

Hanalei Watershed

Hanalei is a small rural community located on the higher ground along the coastline of Hanalei Bay. The major portion of the Hanalei area is in agricultural use; taro fields and pasturelands predominate. Residential and commercial properties are also located in the floodplain, but most are on slightly higher ground. The upper half of the detailed-study section of Hanalei River lies in the Hanalei National Wildlife Refuge.

The plateaus and lowlands extending from Hanalei in the north and clockwise to the Mana-Barking Sands area on the southwest are the island's most fertile lands. The central area, on Kokee Plateau, consists of steep gulches and valleys, bordered on the west by the cliffs of Na Pali and on the east by Alkalai Swamp. The inaccessible sheer cliffs ad mountainous terrain of Na Pali, as well as parts of Kokee, are reserved for conversation and a State Park.

Waipa Stream was studied from its mouth to a point 0.5 mile inland. The stream flows through the agricultural outskirts of the Town of Hanalei and drains an area of 3.2 square miles.

Waioli Stream was studied from its mouth to a point 1.1 miles inland. Its drainage area, extending to the slopes of Namolokama Mountain, which is 4,400 feet high, covers approximately 5.1 square miles. The stream flows on the southwest side of Hanalei.

Hanalei River was studied from its mouth to a point 4.5 miles inland. Its drainage area encompasses approximately 23.8 square miles and drains the northeastern summit slopes of Mount Waialeale. The river flows on the northeastern side of Hanalei and is its primary flooding source.

Anahola Watershed

Anahola Stream flows easterly from the mountains, bisecting the Town of Anahola before emptying into the Pacific Ocean. The upper slopes of the mountains in the Anahola Watershed are predominantly overgrown with thick vegetation.

Anahola Stream drains an area of approximately 10.3 square miles that is approximately 1.5 miles wide and 7 miles long. Anahola Stream was studied in detail from its mouth to a point approximately 0.9 miles inland. The Anahola area is not heavily urbanized. A large portion of the residential area is owned by the Hawaiian Homes Commission. The southeastern bank of the river supports most of the residential homesites, as well as agricultural activities.

Kapaa Watershed

Kapaa Stream was analyzed for flood hazards from its mouth to a point approximately 2.4 miles inland. The stream, draining an area of approximately 16.3 square miles, flows between Kealia and Kapaa. It is the primary flooding source of Kealia, a small rural community located near the coastline north of Kapaa. Upstream of Kealia along Kapaa Stream are large tracts of sugarcane fields.

Moikeha Canal was studied from its mouth to a point approximately 1.4 miles inland. Moikeha Canal drains an area of approximately 2.0 square miles and flows through the northern section of Kapaa. Approximately 45 percent of the drainage area is forested, 50 percent is in sugar cane and grazing fields, and 5 percent is occupied by residential and commercial facilities.

Waikaea Canal was studied from its mouth to a point approximately 1.4 miles inland. Moikeha Canal drains an area of approximately 6.7 square miles and flows through the southern section of Kapaa. The drainage basin has several interconnecting irrigation ditches. Approximately 70 percent of the canal's drainage area is used for sugarcane production, 25 percent is forested, and 5 percent is used for residential and commercial purposes.

Moikeha and Waikaea Canals were built to alleviate the flood problems of Kapaa. However, neither canal has the capacity to contain a 100-year flood, and each is potentially a primary source of flooding for the Kapaa area.

Wailua Watershed

The pear-shaped Wailua River basin extends approximately 11 miles from the ocean on the east to the summit of Mount Waileale in the central part of the island. Its topography is generally hilly and rugged in the upper sections, with a valley plain in the central portion, which terminates in small, flat area at the coast.

Wailua River was studied from its mouth to a point approximately 2.4 miles inland. Its drainage area of approximately 53.1 square miles includes the Opaekaa and Kalama watersheds. The river is the primary source of flooding in the coastal area of Wailua. The land is in agricultural use in the vicinity of the Wailua River and Opaekaa Stream confluence. Commercial and hotel establishments, along with some residences occupy the coastal area on relatively low lands; the average ground elevation is approximately 6 feet in the residential and business area and approximately 4 feet in the agricultural district.

Opaekaa stream was studied from a point approximately 1.0 mile downstream of the Kamalu Road bridge to a point approximately 1.0 mile upstream of its confluence with Opaekaa Tributary. Farmland and pastures predominate in the vicinity of Opaekaa Stream; there is a residential subdivision downstream of Opaekaa Road. Above the confluence with Kalama stream, Opaekaa Stream drains an area of approximately 2.7 square miles. The Opaekaa Stream drainage area above the confluence with Opaekaa Tributary is approximately 2.05 square miles.

Opaekaa Tributary was studied in detail from its confluence with Opaekaa Stream to a point approximately 0.8 mile upstream. The tributary drains an area of approximately 0.39 square mile and mainly flows through farmland and pastures.

Kalama Stream was studied from its confluence with Opaekaa Stream to a point approximately 3.2 miles upstream of the confluence. Draining an area of approximately 2.4 square miles, the stream flows through a relatively wide, flat area occupied by farms, grazing pastures, and open fields.

Lihue Watershed

The Lihue Watershed supports agricultural and commercial activities. Commercial and business centers, a sugar plantation, a major inter-island airport, a deep-draft commercial harbor, and the island's major hospital are the notable developments. Located in the watershed is Lihue, the county seat and commercial center of Kauai.

The watershed extends from the coast to the lower ridges of Mount Waialeale. A significant portion of the developable land is used to grow sugar cane. Several reservoirs built in the watershed serve the sugarcane irrigation system.

Nawiliwili Stream was studied from its mouth to upstream of Lihue, a distance of approximately 3.4 miles. The stream drains an area of approximately 4.7 square miles and is the primary source of flooding for the Lihue and Nawiliwili areas. The upper reach flows through the commercial and industrial are of Lihue. Most of the detailed-study central portion flows through a gulch that is bordered by a few agricultural lands and residences. The residential and commercial areas of Nawiliwili are located near the stream mouth.

Puali Stream was studied from its mouth to a point approximately 0.4 miles inland. The stream flows though the residential area of Niumalu, a small community on the outskirts of Nawiliwili. Its drainage area is approximately 2.0 square miles.

Huleia Stream was studied from it mouth to a point approximately 2.7 miles inland. The drainage area (exclusive of the area controlled by reservoirs) at the stream mouth is approximately 26.07 square miles. Two reservoirs with a total drainage area of approximately 1.48 square miles are located in the upper tributaries. Except for a few houses located near the stream mouth, there are no structures built in the floodplain.

The study reach of the Papakolea Stream was confined to the area near the flood limits of Huleia stream. The drainage are of Papkolea Stream at its confluence with Huleia Stream is approximately 3.48 square miles.

Koloa Watershed

The Koloa-Poipu community is located on the southern coast of Kauai, approximately 8 miles southwest of Lihue. The flood plain contains mostly residential, commercial, and resort development.

The entire length of Waikomo Stream, from its mouth to approximately 4,640 feet upstream of its confluence with Omao Stream, was studied by detailed methods. The upper reach flows through Koloa and is that town's primary flooding source. The central and lower reaches flow mostly through sugarcane fields. The drainage area encompasses approximately 10.4 square miles and includes the Omao and Waihohonu watersheds. There are nine irrigation reservoirs in the Waihohonu watershed; the largest is Waita Reservoir, which has a storage capacity of approximately 2.3 billion gallons of water.

The studied portion of Omao Stream includes its length from the confluence with Waikomo Stream to the spillway crest of Omao Reservoir, a distance of approximately 2.5 miles. The upper and central reaches flow through a gulch. The lower reach flows through sugarcane fields and part of Koloa. The Omao Stream watershed, an area of approximately 4.1 square miles, contains six irrigation reservoirs.

An approximate 1.6-mile section of Lawai Stream, starting approximately 0.9 mile downstream of Kaumualii Highway and ending approximately 0.7 mile upstream of the highway, seas studied. The drainage area is approximately 3.62 square miles and lies mostly in a forest reserve. The floodplain of the study reach is predominately covered with natural vegetation. A few houses, several small cultivated areas, and a warehouse complex are located in the study reach.

Hanapepe Watershed

The Hanapepe River is located in the south-central portion of the island. Its steep slopes induce rapid runoff during heavy rainfall, causing an abrupt rise in streamflow and a low rate of infiltration. The flood plain is roughly triangular and is confined by steep bluffs. Except for several small stores, there are no commercial or industrial establishments within the flood plain.

The Hanapepe River was studied from its mouth to a point approximately 2.2 miles inland. It has a drainage area of approximately 27.0 square miles and drains the southwest summit slopes of Mount Waialeale. The drainage area is relatively long and narrow, approximately 11.5 miles long by 2.5 miles wide. The upper reach studied flows through agricultural lands. The lower reach flows through and is the primary flooding source of the Hanapepe area.

West Kauai Watershed

The West Kauai Watershed extends from the coast to the Waimea Canyon ridgeline. Lying on the leeward side of the island and outside the rain-causing influence of Mount Waialeale, the watershed is fairly dry most of the year.

Flooding from Kekaha Drainageway was studied from the shoreline to a point approximately 3,000 feet inland. The community of Kekaha lies along the coast and is made up primarily of residences and the Kekaha Sugar Mill and its plantation facilities. Upstream and to the sides of Kekaha are sugarcane fields. Kekaha is located on a broad, flat shelf that forms the greater part of the southwestern coastline of the Island of Kauai. The shelf is approximately 10 miles long and approximately 1.5 miles wide, with ground elevations ranging from approximately 8 to 20 feet. The area is devoid of deep, well-defined streams. Most of the watercourses discharging from the numerous valleys upstream of the shelf feed into an irrigation system for the sugar plantation.

Wainiha Watershed

The sparsely populated Wainiha Watershed is a rural environment. Small clusters of residential and commercial (primarily tourist-oriented) areas are located along the coast. Most of the watershed lies in steep, mountainous terrain. Having a northern exposure, the watershed receives a large amount of rainfall from the prevailing tradewinds.

In Wainiha Valley, few houses are located within the study area. The most recently constructed homes near Wainiha River reflect an awareness of proper floodplain management practices. These homes have been elevated by at least one floor height. Most of the valley area is either under cultivation or covered by natural vegetation.

The Wainiha River was studied from its mouth to a point approximately 2.1 miles inland. Its drainage area of approximately 22.57 square miles drains the northwestern summit slopes of Mount Waialeale and is the primary flooding source of Wainiha Valley.

Waimea Watershed

The Waimea Watershed drains the northwestern summit slopes of Mount Waialeale. The uplands contain a large swamp area that drops steeply into several valleys. A forest reserve that encompasses the Waimea Canyon State Park occupies most of the watershed area.

The Waimea River was studied from its mouth, where the drainage area is approximately 86.5 square miles, to a point approximately 1.4 miles inland. Near the mouth on the right bank (looking downstream) is the town of Waimea, where the houses near the river are protected by a flood-control levee. Cultivated fields and natural vegetation occupy the flood plain not protected by the levee.

2.3 Principal Flood Problems

The island of Kauai is subject to flooding from stream overflow, tsunamis, and hurricanes. In some areas along the coast, all three types of flooding may occur. Tsunamis, which are a series of waves generated by submarine earth movements, travel at high velocities and have had a devastating effect on the developed areas of Kauai County. Sources of these tsunamis are varied and are located in North and South America, the Aleutian Islands, Japan, Kamchatka, the islands lying between the Philippines and Samoa, and even Hawaii itself. Within the Hawaiian Islands, the City of Hilo on Hawaii has been most severely damaged from Tsunami impacts. Based on 1970 figures, Hilo had suffered losses of approximately $62 million over the past 50 years.

Although historical records show that hurricane landfall is infrequent, hurricane-induced storm surge and waves pose a flooding threat to the island. Review of hurricane storm-tracks from 1949 to 2008 indicate that only 14 storms Category 1 or higher have come within a 200 nautical mile radius of the Hawaiian Islands as shown in Figure 1, “Hurricane Tracklines.” Kauai Island has been the hardest hit of all the Hawaiian Islands, suffering direct hits from Hurricanes Dot and Iniki. The impacts from these events, in addition to hurricane Iwa are reviewed in the following section.

While the specific cause of tsunami and hurricane related flooding can be attributed to a single factor, the cause of flooding as a result of stream overflow may be due to various reasons. Possible flood causes include: debris-clogged streams, flash floods, undefined streamflow patterns, isolated depressions in topography, inadequate drainage facilities, and changed drainage conditions because of development.

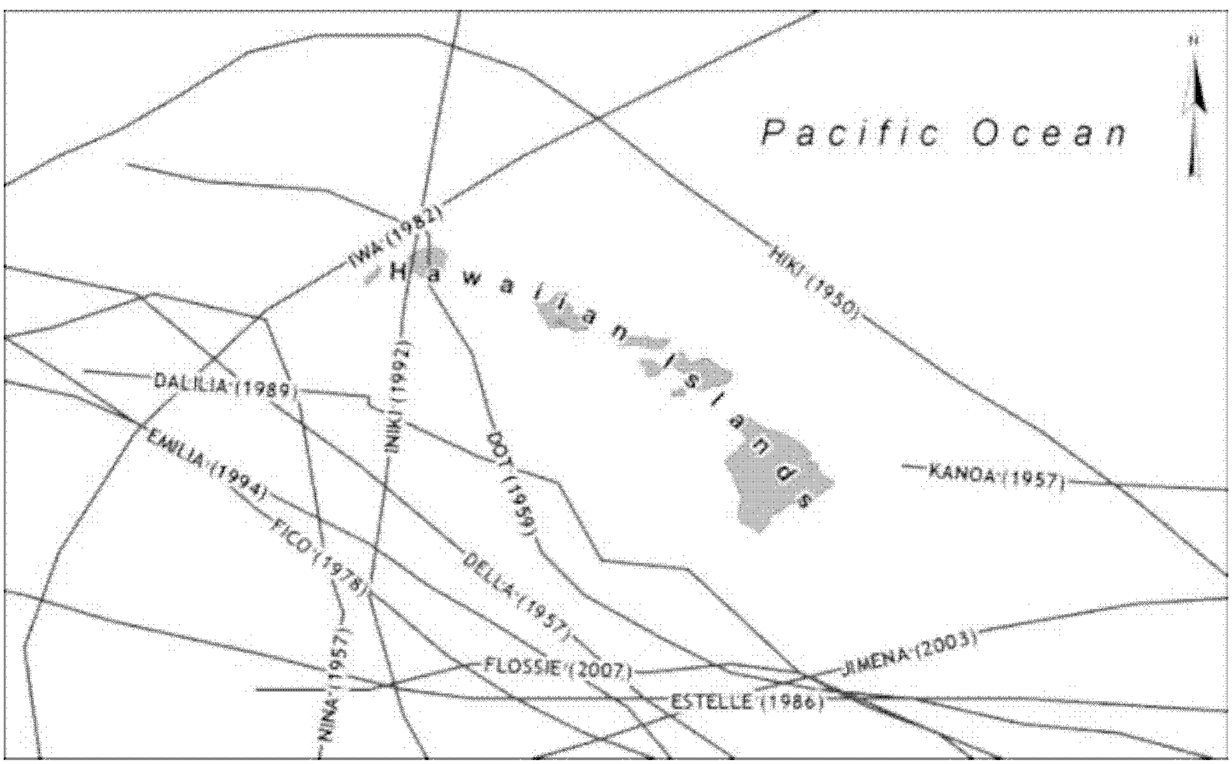


Figure 1 - Hurricane tracklines within a 200 nautical mile radius of the Hawaiian Islands (1949-2008).

Hanalei Watershed

Flood-damage reports for Hanalei span the years from 1877 to the present. Summaries of the more recent floods follow.

In Hanalei, the worst flood on record occurred on November 11 and 12, 1955, and inundated the entire Hanalei Valley lowlands (USACE 1964). An approximately 0.5-mile section of Kuhio Highway was under 6 feet of water; the lowest highway segment was under 8 feet of water. The Hanalei River stream-gaging station, situated at the same location since 1915, was destroyed.

On January 23, 1952, the Hanalei River rose about 10 feet above its normal stage in the area next to the Ching Ma Leong store. A section of Kuhio Highway near the store was covered with water 3 to 4 feet deep. Damage was mainly to crops.

On January 26, 1956, the Hanalei River overflowed and flooded the highway.

On April 17, 1963, the Hanalei River rose to the highest level in several years, but damage was relatively light. The floodwater covered the entire stretch of the low-lying Kuhio Highway.

On April 19, 1974, the Hanalei River overflowed and inundated Kuhio Highway with approximately 3 feet of water. Almost all the taro lands were flooded, and there was damage to crops, equipment, and supplies.

Besides riverine flooding, Hanalei is also exposed to tsunami flooding. On April 1, 1946, the Hanalei area sustained damages to bridge abutments and experienced beach and road erosion. No damage to residences occurred. Maximum wave heights along the shoreline of Hanalei Bay ranged from 9 to 14 feet.

On March 9, 1957, the worst tsunami flooding on record hit the Hanalei area. Major damage to beachfront homes occurred. Nineteen homes were destroyed, and eight were damaged. The in part of the town, the beach road, and its intersection with Kuhio Highway were inundated. No casualties were reported. The maximum wave heights along the Hanalei Bay shoreline ranged from 17 to 19 feet (University of Hawaii, 1976).

The sea produces another type of flooding, from high waves generated by large storms centered offshore. From December 1 to 4, 1969, the highest surf in memory smashed the north and west shores of Kauai (USACE, 1973). In the Hanalei area, approximately 25-foot-high waves destroyed a seawall, washed away the sands at Waioli and Hanalei Parks, partly undermined a bridge, inundated inland areas to depths of almost 1.0 foot, and carried debris inland past the beach road.

Several features of the Hanalei River flood plain aggravate riverine flooding. With low flood discharges, the flow of Hanalei River is impeded by a sandbar at the river's mouth and by thick tree growth encroaching on the riverbanks. With high flood discharges, the dune on which most of the residences of Hanalei are built causes greater flood stages by constricting the flood plain at the mouth of the river.

The stream flows of Waioli and Waipa Streams are obstructed by a sandbar on the coast. The highway bridges over these streams are also restrictive, especially to the high flood flows.

No estimations can be made of the recurrence interval for the worst recorded riverine flood, which occurred on November 11 and 12, 1955, since the stream gage was destroyed by that flood. The April 1974 flood had a peak discharge of 24,900 cubic feet per second (cfs) at a rebuilt stream gage in Hanalei River (USGS, 1975). A frequency analysis of the 14 years of gage record indicates that this flood, the largest of the entire period, had a 5- to 10-year recurrence interval.

Anahola Watershed

The largest flood recorded in the Anahola area occurred on January 25, 1956, when more than 13 inches of rain fell in the watershed within a 24-hour period (USACE, 1996). A U.S. Geological Survey (USGS) stream gage located approximately 3 miles above the mouth of Anahola Stream recorded a peak of 19,600 cfs, the highest in 57 years of stream gage records (USGS, 1964, 1971, 1974, 1976). The flood exceeded the expected 100-year and approached the 200-year flood discharge of the stream gage record. On December 14, 1991, over 20 inches of rain fell during a 12-hour period, resulting in flash floods which recorded five deaths, severe flooding, erosions, and slides, as well as numerous property damages (USGS, 2002). Other major floods occurred in April 1948, August 1959, May 1965, November 1968, and January 1975.

A sandbar built by ocean waves and currents at the mouth of Anahola Stream restricts streamflow and increases flood stages, especially for low flood discharges. Tsunami damage reports are unavailable for the Anahola area. This is probably because the low-lying inland coastal area is largely undeveloped, and houses in the area have been built on higher ground. The highest tsunami wave height recorded in Anahola Bay was 17 feet and occurred in 1946. The maximum wave heights for the 1957 and 1960 tsunami were 16 feet and 6 feet, respectively.

Kapaa Watershed

From records of nearby watersheds, it is estimated that the two largest recent floods in the Kapaa area occurred in October 1955 and January 1956 (USACE, 1974). During the 1955 flood, several small boats were swept out to sea by floodwater from Waikaea Canal.

A stream gage, operating in Kapaa Stream since 1962, recorded the highest discharge, 16,200 cfs, in January 1975, a magnitude that approximated the 10-

year flood frequency of the gage record. There was flooding along the banks of Kapaa Stream, and the Kuhio Highway Bridge was partially undermined. The second highest discharge at the stream gage occurred on November 29, 1968. The peak discharge of 12,800 cfs inundated over 100 acres of sugarcane, and water stood over 5 feet deep in the lower areas near Kealia. Cane haul roads and a bridge were severely damaged, as were plant nurseries and vegetable crops.

The flood history in the Kapaa area is not well documented. Before construction of Moikeha and Waikaea Canals, flooding occurred periodically from sheet runoff, but since completion of the canals, there has been no extensive flood damage. Several factors aggravate flooding in the area. Debris buildup at the highway bridges over Kapaa Stream and siltation and plant growth within Moikeha and Waikaea Canals are the main problems.

The 1946 tsunami was the most devastating to hit the coastal areas of Kapaa and Kealia. The maximum wave heights were 12 feet at Kapaa, approximately 25 feet in the area between Kapaa and Kealia, and 18 feet at Kealia. Several homes in the Kapaa area were damaged. The tsunami flooded Kapaa Park to a depth of approximately 1.0 foot and washed 300 yards inland. The other major tsunami that struck the Hawaiian Islands in 1957, 1960, and 1964 produced a maximum wave height of only 7 feet along the Kapaa-Kealia coastline.

Wailua Watershed

Flood damage reports are non-existent for the Kalama Stream because of the generally undeveloped nature of the area. The stream has no gaging station.

Flood problems from Opaekaa Stream have mostly occurred upstream of Kamalu Road, where, before 1976, a 6-foot-square box culvert restricted flood discharges (USACE, 1973). The box culvert has since been replaced by a bridge. The largest recorded flood in the watershed, measured at a gaging station with 15 years of records, located in the left branch of Opaekaa Stream, occurred on January 31, 1975. It had a peak discharge of 724 cfs, which is equivalent to approximately a 28-year recurrence interval. Flood problems caused by Opaekaa Tributary and the upstream study reach of Opaekaa Stream have not been documented.

The largest recorded flood on the Wailua River inundated half of the Wailua residential area on April 15, 1963. During the storm, the South Fork Wailua River stream gage recorded a discharge of 87,300 cfs, the highest in its 62 years of record. The frequency of the discharge was approximately equal to the 200-year recurrence interval of the gage record. On the same date, the North Fork Wailua River gage recorded a discharge of 21,000 cfs, the second highest recorded there. Based on a frequency analysis of its 23 years of record, this discharge had a 10- and 25-year recurrence interval.

The lower 2-mile-long segment of the Wailua River has an estimated channel capacity of 35,000 cfs, which has frequently been exceeded (USACE, 1970). At least 20 major floods have been recorded on the river since 1912. In 1955, the Coco Palms Hotel dining room was inundated to a depth of approximately 5 feet.

The latest flood, which occurred on January 31, 1975, rose to a stage that nearly inundated the road leading into the Wailua Homestead area. Flood problems on the Wailua River are aggravated by accumulation of debris at the highway bridge piers.

Coastal areas of Wailua are also subject to tsunami flooding. Twelve-foot-high waves generated by the 1946 tsunami damaged several homes and inundated the Coco Palms Hotel and adjacent lowland areas to depths of 2 to 3 feet. Higher tsunami wave heights, ranging from 10 to 20 feet, were recorded in 1957 in the Wailua area. Lesser waves, 5 feet high, were caused by the 1960 and 1964 tsunami.

Lihue Watershed

The worst flood on Nawiliwili Stream occurred in April 1963, when the stream overflowed and inundated the low-lying coastal area (USACE, 1975). Sugarcane fields were also damaged. The storm's recurrence interval could not be estimated, because the stream has no gaging station and high-water data were not available. Other floods occurred on this stream in 1920, 1921, 1928, 1950, 1956, and 1970.

The lowlands of the Puali and Nawiliwili Streams are particularly vulnerable to inundation. Sand buildup at the mouth of Nawiliwili Stream causes backwater in the lower portions. To add to the problem, debris accumulation at the bridge openings has aggravated floods in the upstream areas, especially upstream of the Rice Street bridge. In the past, the lawns, parking lots, and roads near Puali Stream have been inundated by sheet runoff and stream overflow. Low spots in residential areas have been covered with standing water to depths of 1 to 2 feet.

Huleia Stream does not have a well documented flood history. The only source that provides some insight on the past flood events is the Huleia Stream gaging station. The stream gage has a 22-year record (1962 to 1983), has a drainage area of approximately 17.6 square miles, and is 4.7 miles from the mouth. The highest peak discharge of 26,800 cfs (a 45-year recurrence interval at the gage site) recorded on November 28, 1970. The Niumalu community borders the mouth of Huleia Stream.

The coastal areas of Nawiliwili and Niumalu have also been inundated by tsunami. The 1946 tsunami produced the highest waves, ranging from 7 to 14 feet high, destroying or damaging a number of homes and businesses and inundating the low-lying areas to depths of 4 to 5 feet. Minor flooding was caused by the 1957 and 1960 tsunami, which produced wave heights varying from 4.5 to 10 feet in the Nawiliwili Bay area.

Koloa Watershed

Properties in Koloa in the vicinity of Waikomo Stream and Waikomo Road are particularly flood prone. Debris and vegetation growth in the stream channel aggravate the flood problem in this area. Although Waikomo Stream has caused flooding in Koloa, the major flood problem area is the coastal region of Koloa-

Poipu, where shallow flooding caused by low-lying topography and inadequate drainage facilities frequently occurs. From six storms that caused flooding in the low-lying Koloa-Poipu area from 1954 to 1965, no flood damages were reported in areas adjacent to Waikomo Stream (USACE, 1966). A summary of recent flood reports for Waikomo Stream follows.

On April 19, 1974, Waikomo Stream overflowed and partially inundated several homes and lawns adjacent to the stream in Koloa. Most damage was caused by the accumulation of debris and silt (USACE, 1974).

On January 31, 1975, Waikomo Stream flooded the Town of Koloa. About 30 people had to be evacuated from their homes. This is the largest known flood on record, but because the stream has no gaging station and high-water marks are unavailable, a recurrence interval was not estimated.

There is no published material on past floods on Omao Stream. A November 1976 field interview of local residents revealed that Omao Stream had overflowed six or seven times in the past 20 years. Based on these interviews, the January 31, 1975, flood was determined to be the worst.

No tsunami damage has been recorded for the coastal area of Waikomo Stream. The 1946, 1957, and 1960 tsunami generated maximum wave heights of 8 feet, 9 feet, and 2.5 feet, respectively, in the vicinity of Waikomo Stream.

In 1982, Hurricane Iwa was the cause of damage along the coastal area of Waikomo Stream. Before this hurricane, the coastal inundation caused by hurricanes passing by was not significant. Hurricane Iwa had a maximum wave height of 14 feet.

Hurricane Iniki reached Kauai on September 11, 1992. With winds topping out at 125 miles per hour, it was the costliest and most powerful hurricane on record in Hawaii. The most extensive damage on Kauai was along the southern coast in the Poipu area. Most of the damage incurred on Kauai occurred in the span of less than one hour (USGS, 2004).

Heavy winds caused widespread structural damage. Many homes were leveled or lost their roofs. Red Cross figures stated that 14,350 homes were damaged, with about 10% of those homes being completely destroyed (NOAA, 2003).

Storm surge and wave action caused additional damage, destroying 63 homes (1). Hurricane Iniki “caused massive beach-face erosion and overwash of the coastline which penetrated up to [984 feet] (300 m) reaching elevations of nearly [29.5 feet] (9 m)” (USGS, 2004).

There is no published information on flood problems within the study reach of Lawai Stream. Flood problems on a tributary to Lawai Stream (USACE, 1973) and a brief description of a 1963 flood event in the Kalaheo-Lawai area (USGS, 1963) provide correlative information. Within the study reach, the only information that reflects the severity of past floods was provided by a note made on a bridge plan (dated October 1928) to widen the arch bridge at Lauoho Road (Kauai County, 1928). On the bridge plan, it was noted that the bridge deck was damaged by a flood. Based on the hydrologic and hydraulic analyses made for this Flood Insurance Study, the flood that damaged the bridge deck (assuming no debris blockage of the bridge opening) exceeded the 100-year flood.

The Lawai Stream gaging station, located approximately 2.1 miles downstream of Lauoho Road bridge, provides recorded peak-discharge data. The stream gage, which has a 22-year record (1962 to 1983) and a drainage area of 6.62 square miles, recorded the highest peak discharge of 5,810 cfs on January 31, 1975. The peak discharge was equal to a recurrence interval of 30 years at the gage site.

Hanapepe Watershed

The largest recorded flood in the Hanapepe area occurred on April 15, 1963. During the storm, the Hanapepe River gaging station recorded its highest discharge (39,000 cfs) in 47 years of record. The discharge approximated the magnitude of the 0.5% annual chance flood frequency. The flood destroyed several homes and severely damaged many more in the Hanapepe Valley area. A USACE flood-control levee project under construction at the time was also severely damaged.

Since the completion of the levee project, the low–lying areas have been beset with interior drainage problems. In December 1968, several homes and lawns behind the levees were flooded to depths of 3 to 4 feet by floodwater discharged from nearby Hikiula Gulch.

Another low-lying area, situated between Hanapepe Road and the river mouth, is still flood prone, since the levees were not continued to the mouth. A sandbar encroaches on the river mouth and increases the flood potential of the area.

Tsunamis have inundated the coastal area of Hanapepe. Within Hanapepe Bay, the tsunami wave heights ranged from 7.5 to 14 feet for the 1946, 1957, and 1960 tsunami. The 1946 tsunami damaged army garrison facilities at Hanapepe Beach and inundated low–lying areas. Besides tsunami waves, high waves generated by the 1950, 1957, and 1959 hurricanes also caused damage in the Hanapepe Bay area

West Kauai Watershed

The largest recorded storm in the Kekaha area occurred on December 1973. Intense rainfall (7 inches of rain within 2 hours) floodwater throughout Kekaha, inundating the Hawaiian Homes area and damaging Cox's Ditch. County and State roads about 50 homes sustained damage. Also flooded were sugarcane fields, which sustained damage from rock and debris deposition and topsoil erosion. According to several local residents, the flood was aggravated by nonnatural sand plugs in the drainageways near Kekaha. The flood was estimated by the SCS to have 15-year recurrence intervals

On January 31, 1975, another storm occurred that flooded homes, blocked traffic, and eroded roadsides. No damage estimates are available for that storm.

Typical of the coastal towns of Kauai, Kekaha is vulnerable to tsunami flooding. The runup from the 1946 and 1960 tsunami washed over the highway and flowed 100 to 200 feet inland, inundating properties to a depth of 1 to 2 feet. The wave heights for the 1946, 1957, 1960, and 1964 tsunami were fairly uniform, varying from 8 to 10 feet along the Kekaha coastline.

Kekaha is also exposed to high waves generated by hurricanes and large storm formations centered offshore. The high waves of the 1950, 1957, and 1959 hurricanes eroded the shoreline areas, and the December 1969 storm sent waves, which were up to 30 feet high at the shoreline, across the highway (USACE, 1970).

<u>Wainiha Watershed</u>

Three severe floods have occurred on the Wainiha River. On February 17, 1956, more than 20 inches of rain fell in the valley during a 24-hour period (USACE, 1973). The Wainiha River stream gage, located 6.8 miles from the mouth with a drainage area of 10.2 square miles, was destroyed (USGS, 1971). From flood marks at the stream gage, a peak discharge of 40,000 cfs was calculated.

The peak discharge was the highest recorded in the 30-year (1953 to 1983) stream gage record and equaled the 170-year flood at the gage site.

During a 4-day period of November-December 1968, approximately 15.47 inches of rain recorded at the Wainiha Powerhouse rain gage and 29 inches (estimated at the Wainiha Power Canal Intake rain gage (USACE, 1969). The discharge at the stream gage was not determined. Taro patches near the stream were either washed away or covered with mud and debris. The flood plain in the downstream reach (up to the 20-foot contour area) was inundated to depths of 2 to 3 feet. The two wooden bridges at Kuhio Highway that span the in stream and the side branch on the in stream were damaged. Further up the valley, hillside runoff caused road washouts and landslides. The generator units and part of the building of the Wainiha Powerhouse were damaged by a landslide and sustained damages.

On April 19, 1974, approximately 11.5 inches of rain fell at the Wainiha Power Canal Intake rain gage and approximately 9.2 inches at the Wainiha Powerhouse rain gage during a 24-hour period (USACE, 1974). The Wainiha River stream gage recorded a peak discharge of 28,100 cfs, which is equal to a 45-year flood at the gage site. Residents in the valley were adversely affected. One child drowned, and another child survived after being swept 600 feet downstream. Several homes and cars were destroyed. Eleven residents were evacuated by helicopter from the flooded valley area. The floodwater inundated 100 acres of land up to 7 feet deep and heavily damaged the taro crop. Inlets to two irrigation ditches were blocked with huge boulders and silt. The intake tunnel for the Wainiha Powerhouse was damaged. At the peak of the flood, Kuhio Highway was under 5 to 6 feet of floodwater. The two highway bridges were, however, not structurally damaged (USACE, 1975).

Besides being vulnerable to riverine flooding, Wainiha Valley is prone to flooding from high-surf conditions and tsunami. Of the two coastal flooding sources, tsunami have produced the greater flood damages. The two most severe tsunami to hit Wainiha Valley occurred in 1946 and 1957.

In the 1946 tsunami, 19 persons were reported dead or missing in the Wainiha and surrounding watersheds. At Wainiha Valley, tsunami waves swept up to the 27-foot contour elevation and destroyed both bridge spans at Kuhio Highway. The floodplain was inundated by seawater 2 to 3 feet deep.

The 1957 tsunami, the most destructive tsunami to hit the Wainiha Watershed, destroyed or damaged 81 homes, destroyed 7 boats, and left 175 persons homeless in the Wainiha and nearby watersheds. In the Wainiha Bay area, tsunami flood elevations ranged from 38 to 53 feet (University of Hawaii, 1976). In Wainiha Valley, low-lying areas 4,000 to 5,000 feet inland were inundated. The tsunami waves pushed a home more than 1,000 feet inland and destroyed the two bridges on Kuhio Highway.

<u>Waimea Watershed</u>

On several occasions, Waimea River flooded the Waimea Town area. Severe floods dating back to 1916, 1921, 1927, and 1942 were recorded. On February 7, 1949, the most destructive flood occurred; two lives were lost and five houses were destroyed (USACE, 1994). The entire town was flooded; the business center was flooded to depths of 3 to 8 feet. Several commercial structures were shoved off their foundations. During the flood, the Waimea River gaging station (Station 380) recorded its highest stage height of 11.4 feet. (Peak discharges are not determined for this stream gage.) The stream gage has a 39-year record (1944 to 1983) and is located 150 feet upstream of the Kaeualii Highway bridge. Based on the river-stage data, the 1949 flood was equal to a 55-year flood.

On August 16 and 17, 1950, the Waimea River overflowed twice and flooded the nearby streets to depths greater than 4 feet. More than 200 residents were evacuated from the valley.

On April 19, 1974, more than 22 acres of cultivated land in upper Waimea Valle were flooded to depths of 3 to 5 feet. The corn and taro crops suffered damages. The flooded area was protected by a privately built levee, which failed during the storm.

Since 1907, flood-control measures have been taken to protect the town, primarily the construction of a levee system. In 1952, substantial improvements were made to the flood-control system. In 1985, the levee was improved to provide protection from the 1-percent annual chance event flood.

With the construction of the levee system, interior drainage problems became more pronounced. On December 1, 1973, the ditch in lower Waimea Valley overflowed and flooded adjacent properties. Blockage of drain pipes and ponding occurred. On January 31, 1975, overflow from the ditch flooded the low-lying areas. Flooding was primarily caused by the closure of the outlet flood gates, which were kept shut as a result of high flood stages on the rivers.

Coastal Area

Hurricane Dot made landfall on the island of Kauai on August 6, 1959 as a Category 3 storm. Sustained winds of 81 mph, with wind gusts of 103 mph, were recorded at Kilauea Light, and damaged vegetation indicated that winds may have exceeded 125 mph in some locations (National Weather Service, 1959). A peak storm surge of 2.6 feet was recorded in Nawiliwili Harbor on the island of Kauai. On Oahu Island, damage was limited to rain-induced flooding and localized wind damage. The island of Hawaii experienced local flooding related to torrential rainfall in addition to minor wave damage near South Point and along the Kona Coast (National Weather Service, 1959).

Hurricane Iwa caused severe wind damage to Kauai Island and notable wave damages to the southwest facing coasts of all islands, although it did not make direct land fall on any of the Hawaiian Islands. Hurricane Iwa passed to the north of Kauai as a Category 1 hurricane on November 11, 1982. The south shore of Kauai and the Waianae coast of Oahu experienced sever wave damage. Total damages from the storm were estimated at $250 million, in 1982 dollars (National Weather Service, 1982).

The storm-of-record for the Hawaiian Islands is Hurricane Iniki. Hurricane Iniki made landfall on the island of Kauai on September 11, 1992 as a Category 4 storm with maximum sustained winds over land at 140 mph with gusts as high as 175 mph. Extensive wind, wave and surge damage occurred along the south coast of Kauai, damaging or destroying 14,350 homes (National Weather Service 1992). A peak surge of 4.1 feet Local Tidal Datum was observed by a water level station in Nawiliwili Harbor on the Island of Kauai.

2.4 Flood Protection Measures

Due to the relatively undeveloped nature of Kauai County, flood-protection measures on the island are few. The county uses flood plain information reports on several flood-prone areas, provided by State and Federal agencies, in its flood plain management efforts.

The only flood-control structures on Kauai Island are in the Hanapepe, Waimea, and Kapaa districts. Most of Hanapepe is protected by a USACE flood-control project that consists of levees on both banks of the Hanapepe River. The levees start upstream of the Hanapepe Road Bridge and are designed to contain a 0.2% annual chance event discharge of 52,000 cfs.

In the Kapaa district, the Moikeha, Waikaea, and Waipouli Canals were built by the county to provide flood protection. The 1-percent annual chance flood event will overflow in some sections, but for the most part it will be contained by the 4,600-foot-long Moikeha Canal. The capacity of the Waikaea Canal will be slightly exceeded by a 10-year flood. The Waipouli Canal runs along the Kuhio Highway and intercepts runoff from areas do slope of the Wiaikaea Canal.

FEMA specifies that all levees must have a minimum of 3-foot freeboard against 1-percent annual chance flood event to be considered a safe flood protection structure and meet the requirements of 44 CFR 65.10.

There is a levee on the west bank of the Waimea River, built to provide 1-percent annual chance flood event protection for Waimea (State of Hawaii, 1963). In 1985, improvements to the levee system on the west bank of the Waimea River were made by the USACE. The project protects the town from the 1-percent annual chance flood event. For the interior drainage of the area upstream of the highway, the design of the project provides for an operating headwater elevation of 5.7 feet for the 1-percent annual chance interior flood. The project consisted of installing two drainage outlet structures: five 60-inch pipe culverts located just upstream of the highway, and a 24-inch pipe culvert, approximately 100 feet downstream of the highway extending the levee from the highway to the river mouth, constructing a floodwall on the existing levee, and providing toe protection for the existing levee.

Kauai County has many reservoirs, which are primarily used for agricultural irrigation purposes. A few are used to generate hydroelectric power. They provide some storage capacity, but are not effective in providing complete flood protection to downstream areas. The county government has installed drainage facilities, improved existing drainage facilities, and replaced old restrictive culverts with larger bridges in an effort to alleviate flood problems.

Special storm warnings for Kauai County are broadcast over local radio and television stations. At the best, these warnings can only be made for broad, general areas of the island because of the “flash" nature of floods in Hawaii. A tsunami warning system has been developed for the entire State of Hawaii. This warning system is designed to provide sufficient time for evacuation of residents from the tsunami danger zones.

3.0 ENGINEERING METHODS

For the flooding sources studied in detail in the community, standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this FIS. Flood events of a magnitude that are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 50-, 100-, and 500-annual flood events, have a 10%-, 2%-, 1%-, and 0.2%- annual chance, respectively, of being equaled or exceeded during any year. Although the recurrence interval represents the long-term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. For example, the risk of having a flood that equals or exceeds the 100-year flood (1-percent chance of annual exceedence) in any 50-year period is approximately 40 percent (4 in 10), and, for any 90-year period, the risk increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials based on conditions existing in the community at the time of completion of this FIS. Maps and flood elevations will be amended periodically to reflect future changes.

3.1 Hydrologic Analyses

Hydrologic analyses were carried out to establish the peak discharge-frequency relationships for each flooding source studied in detail affecting the community.

Areas subject to riverine flooding, a multiple regression study was conducted for the Island of Kauai in accordance with principles and procedures presented in Statistical Methods in Hydrology (USACE, 1962). The frequency method used in this study is that recommended in the Water Resources Council (WRC) bulletin, "Guidelines for Determining Flood Flow Frequency" (WRC, 1976). Data from 28 stream-gaging stations were used in the analysis; the average length of record was 29 years, and the longest was 62 years. Gages with less than 8 years of record or with a high degree of regulation and/or diversion were not used in this study.

Using the techniques described in Statistical Methods in Hydrology, multiple linear correlations of the geometric mean flood (dependent variable) to the physiographic and meteorological characteristics (independent variables) of the basin at each station were made. From regional correlation studies, the following equation was adopted:

$$Qp = Cp\ DAO.58\ CLO.66PA1.07$$

where, Qp is the runoff in cfs for a 2-year recurrence interval;
DA is the drainage area in square miles;
CL is the length of the channel in miles;
PA is the average annual precipitation in 100 inches; and
Cp is the peak runoff coefficient that accounts for factors influencing runoff.

Regression analyses were made between standard deviation of runoff logarithms and drainage basin characteristics, but it was found that very little correlation existed. Hence, extended standard deviations were plotted on a map to draw isopleths of the standard deviations. Skew coefficients were adopted from the aforementioned WRC bulletin (USDA, Unpublished).

Modifications were s:de to the standard hydrologic analyses for the Moikeha, Nawiliwili, Omao, Waikaea, and Waikomo drainage areas. The peak discharges for these drainage areas were lessened by the attenuating effects of the reservoirs and diversionary ditches located in the watersheds.

Improvements were made to the regional equation and methodology for Wainiha River, Opaekaa Stream, Opaekaa Tributary, and Lawai Stream by using additional peak-discharge data and by developing regional equations that were solved directly for the 10-, 2-, 1-, and 0.2-percent annual chance peak discharges. This improved methodology was used in the development of discharge data for Wainiha River, Opaekaa Stream, above Opaekaa Tributary), Opaekaa Tributary, and Lawai Stream. Frequency analysis of the peak discharge data and the development of the regional equations were similar to those for the May 1981 FIS (FEMA, 1981). For this study, peak-discharge data from 33 gaging stations were used. The average length of gage record was 31 years, and the longest length was 67 years.

For the development of the regional equations, a multiple regression analysis was made to correlate peak discharges for a selected frequency to the physiographic and meteorological characteristics of the gaged area. From the regression analysis, the following equations were selected and used for this study:

Q2YR	595 DA0.858
Q10YR	1285 DA0.861
Q50YR	1285 DA0.861
Q100YR	2045 DA0.862
Q500YR	2405 DA0.863

Where, Q2YR is the peak discharge for the 2-year flood in cfs;
Q10YR, Q50YR, Q100YR, and Q500YR are similarly defined as the peak discharges for the 10-, 2-,1-, and 0.2-percent annual chance floods, respectively, in cfs; DA is the drainage area in square miles.

Modifications were made to the regional equations for streams with stream gage data. At the stream gage site, the frequency curve based on the stream gage data was compared against the frequency curve based on the regional equations. A weighted frequency curve was then drawn that gave greater weight to the more frequent floods (e.g., the 2-year flood) of the stream gage data and greater weight to the rarer floods (e.g., the 1-percent annual chance flood) as predicted by the regional equations. The regional equations were then modified (the coefficients revised but the exponential value kept constant) to describe the weighted frequency curve. The modified regional equations were subsequently used for the study reach of the stye

The regional equations were modified for the Wainiha River, Opaekaa Stream, and Opaekaa Tributary, and Lawai Stream.

Although Huleia Stream has stream gage data, the regional equations were not modified because the 2-year peak discharges for the stream gage data and the regional equation are similar.

For Kekaha Drainageway, a flood hydrograph was developed because the hydraulic analysis of the area involved a flood-routing procedure. Snyder's unit hydrographs were developed for the study area. The unit hydrograph parameters and infiltration loss rates were based on values obtained from flood reconstitution analyses of the Waimea and Makaweli River basins (USACE, 1994). Rainfall data were obtained from the Rainfall-Frequency Atlas of the Hawaiian Islands (USDoC, 1962). The 1-percent annual chance-rainfall data were used to develop the 1-percent annual chance flood hydrograph.

For Waimea River, the peak discharges for the selected frequencies were obtained from a Waimea River detailed project report (USACE, 1994). In the report, the hydrologic investigation used recorded flood hydrographs of upstream stream gages in the Waimea and Makaweli Rivers. The flood hydrographs were routed and combined to determine the peak discharges at Waimea Town. In this manner, a 34-year record (1944 to 1977) of peak discharges was developed for Waimea River at the town site. The peak discharges for the selected frequencies were then obtained by performing a frequency analysis on the 34-year record.

Peak discharge-drainage area relationships for the riverine flooding sources studied in detail are shown in Table 1.

Flood discharges for areas of approximate study were derived from various hydrologic studies and are grouped into two general categories:

1. Discharges determined by the detailed hydrologic analyses formulated for this study.

2. Discharge data extracted from prior studies, with which frequency analyses were performed on the peak discharges of stream gage records.

A summary of the drainage area-peak discharge relationships for the streams studied by detailed methods is shown in Table 5, "Summary of Discharges."

TABLE 5 - SUMMARY OF DISCHARGES

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs)			
		10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
ANAHOLA STREAM					
At mouth	10.3	15,000	24,000	29,000	42,000
HANALEI RIVER					
At mouth	23.8	37,000	51,000	58,000	73,000
HANAMALULU STREAM					
At mouth	8.9	*	*	27,300	*
HANAMALULU STREAM TRIBUTARY					
At mouth	*	*	*	11,193	*
HANAPEPE RIVER					
At mouth	27.0	21,000	32,000	38,000	52,000
At Gage No. 16049000	18.5	17,000	26,000	31,000	42,000
HULEIA STREAM					
At mouth	26.07	21,270	34,020	40,160	56,190
At a point approximately 13,800 feet inland	19.82	16,800	26,860	31,700	44,330

*Data not available

TABLE 5 - SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
KALAMA STREAM					
At confluence with Opaekaa Stream	2.4	3,800	6,600	8,200	12,200
KAPAA STREAM					
At mouth	13.6	21,000	32,000	37,000	51,000
KEKAHA DRAINAGEWAY					
Waipao-Waika Basin	5.54	*	*	8,605	*
Kapilimao-Waimea Basin	5.79	*	*	10,650	*
Drainageway between basins	5.54	*	*	5,550	*
LAWAI STREAM					
At Lauoho Road	3.62	3,090	5,470	6,650	10,170
At upstream Access Road crossing	3.32	2,870	2,070	6,170	9,440
MOIKEHA CANAL					
At mouth	2.0	900	1,300	1,500	1,900
NAWILIWILI STREAM					
At mouth	4.7	2,400	6,350	10,400	19,000
At Lihue Mill Access Road	4.0	2,250	5,800	9,450	17,400
OMAO STREAM					
At confluence with Waikomo Stream	4.1	2,700	3,900	4,400	5,700
OPAEKAA TRIBUTARY					
At confluence with Wailua River	6.4	9,000	15,200	18,500	27,500
Downstream of confluence of Kalama Stream	5.1	7,300	12,200	15,500	22,200
Upstream of confluence of Kalama Stream	2.7	4,300	7,600	9,400	14,000
Downstream of confluence of Opaekaa Tributary	2.44	1,810	3,440	4,390	7,230
Upstream of confluence of Opaekaa Tributary	2.05	1,560	2,960	3,775	6,200
At Access Road crossing	1.80	1,395	2,650	3,375	5,550
At confluence of Opaekaa Stream	0.39	370	710	900	1,480
At Poo Road	0.36	350	660	840	1,380

*Data not available

TABLE 5 - SUMMARY OF DISCHARGES - continued

FLOODING SOURCE AND LOCATION	DRAINAGE AREA (sq. miles)	PEAK DISCHARGES (cfs) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
PAPAKOLEA STREAM					
At confluence with Huleai Stream	3.48	3,760	6,000	7,060	9,830
PUALI STREAM					
At mouth	2.0	3,000	5,400	6,600	9,700
WAIKAEA CANAL					
At mouth	6.7	3,300	4,700	5,400	6,900
WAIKOMO STREAM					
At mouth	10.4	5,600	7,900	9,000	11,600
Downstream of confluence of Omao Stream	7.9	4,200	6,000	6,900	8,900
Upstream of confluence of Omao Stream	*	*	*	2,500	*
WAIKOMO STREAM TRIBUTARY					
At confluence with Waikomo Stream	*	*	*	670	*
WAILUA RIVER					
At mouth	53.1	40,000	64,000	76,000	105,000
WAIMEA RIVER					
At mouth	86.5	35,500	54,500	64,000	89,000
Upstream of confluence with Makaweli River	58.4	28,900	45,300	53,300	74,600
WAINIHA RIVER					
At mouth	22.57	29,700	46,600	55,590	76,560
At a point approximately 8,800 feet inland	20.68	27,550	43,220	51,540	70,980
WAIPA STREAM					
At mouth	3.2	5,000	8,800	10,500	16,000
WAIOLI STREAM					
At mouth	5.1	7,400	12,500	16,000	23,000

*Data not available

Analyses were carried out to establish the peak elevation-frequency relationships for each coastal flooding source studied in detail.

Tsunami wave elevations for the coastal areas of Kauai were calculated using a report prepared by the USACE Waterways Experiment Station (Houston, et al., 1977). A hybrid finite-element numerical model developed to supplement historical data in determining the 10 largest tsunami elevations from 1837 to 1979 The model provides an accurate and representative response of the island to tsunami activity due to rapid bathymetric and/or wave height variations. The numerical model was adjusted and verified by comparing the calculated results of the model with tidal gage recordings of the 1960 and 1964 tsunami. Use of the model yields starting tsunami elevations for various flood frequencies at a point 200 feet inland from the shoreline.

The tsunami model was improved by using additional data and by including the effects of Hurricane Iwa. The coastal inundation elevations near the shoreline caused by tsunami and hurricane Iwa were combined and treated as a single sample of the parent population of coastal inundation elevations. A frequency analysis was then made on the sample population (the inundation data) to determine the near-shore coastal flood elevations for the selected frequencies for the Kekaha to Poipu Area.

The 1- and 0.2-percent annual chance flood elevations along the shores of Kekaha-Poipu were revised to include the effects of Hurricane Iniki described in a report entitled “Hurricane Iniki Coastal Inundation, September 11, 1992,” prepared by the USACE, Pacific Ocean Division (USACE, 1994). To include the effects of Hurricane Iniki, the tsunami model (Houston, et al 1977) was improved using the same methodology that was used to include the effects of Hurricane Iwa when the study was revised in 1985. The coastal inundation elevations near the shoreline caused by tsunami and Hurricanes Iwa and Iniki were combined into the population of coastal inundation elevations (Houston, et al 1977). A frequency analysis was then made to the data population to determine the coastal flood elevations for the selected frequencies for the Kekaha to Poipu Areas (USACE, 1994).

The Advanced Circulation model for Coastal Ocean Hydrodynamics (ADCIRC), (Luettich, 1992), developed by the USACE was selected to develop the stillwater elevations or storm surge for the State of Hawaii. ADCIRC is a two-dimensional depth integrated, finite element, hydrodynamic model that solves the equations of motion for a moving fluid on a rotating earth. Water surface elevations are obtained from the solution of the depth-integrated continuity equation in the generalized wave continuity equation form, whereas velocities are obtained from the solution of the two-dimensional momentum equations. The model has the capability to simulate tidal circulation and storm surge propagation over large domains and is able to provide highly detailed resolution along the shoreline and other areas of interest.

The Empirical Simulation Technique (EST), also developed by the USACE Scheffner et al. (1999), was used to develop the stillwater frequency curves for the 10-, 2-, 1-, and 0.2-percent annual chance stillwater elevations.

The ADCIRC grid was sourced from an existing grid developed by the USACE. The USACE grid was used for offshore areas, whereas new higher resolution nearshore and topographic coverage was added around the islands of Kauai, Oahu, Molokai, Lanai, Maui, and Hawaii. The greater part of the bathymetric data set was comprised of 255 individual NOAA NOS hydrographic surveys, collected from 1900 to 2005. The USACE Joint Airborne LiDAR Bathymetry Technical Center of Expertise (JALBTCX) provided bathymetric LiDAR collected in 1999 and 2000. This dataset provided high-resolution coverage of the nearshore bathymetry, where available. The USACE Honolulu District provided a 2004 hydrographic survey of Honolulu Harbor. A 2004 multibeam survey of Pearl Harbor conducted by the U.S. Navy was provided by the NOAA National Geophysical Data Center. All soundings were converted to the MSL datum using relationships developed from NOAA gages. Finally, all datasets were merged and overlapping data were removed to leave the best possible data.

The topographic portion of the ADCIRC grid was populated with LiDAR data collected for the project along the southern coasts of the six islands included in the study. The LiDAR data were collected in fall of 2006, post-processed to bare earth and quality controlled to meet FEMA mapping standards. To facilitate use with ADCIRC, elevations were converted to meters. LiDAR elevations were delivered in the Local Tidal Datum; therefore no vertical datum conversion was necessary.

Wind and pressure fields were required for input. A model called the Planetary Boundary Layer model (PBL), developed by V.J. Cardone (Cardone, 1992) was used for this study. The PBL model uses the parameters from a hurricane or tropical storm to simulate the event and develop wind and pressure fields. The PBL model simulates hurricane-induced wind and pressure fields by applying the vertically integrated equations of motion.

The storms applied in this study were selected so as to represent the range of different storm magnitudes impacting the study area. Storm selection was limited to events passing within 200 statute miles of at least two islands in the study area. In total, 11 hurricane and tropical storm events were selected for storm surge modeling. Due to the low number of historical storms identified in the storm selection, the historical storm events were duplicated and shifted laterally by one radius to maximum winds in order to represent the potential range of tracks that future storms may take. In total, 100 storms were generated for developing stillwater elevations within the study area.

TABLE 6. SUMMARY OF HISTORICAL STORM EVENTS SELECTED FOR DEVELOPMENT OF STORM SURGE ELEVATIONS

Name of Storm	**HURDAT ID#**	**Begin Date**	**End Date**
Tropical Storm Hiki	10	August 12, 1950	August 21, 1950
Tropical Storm Della	65	September 1, 1957	September 11, 1957
Tropical Storm Nina	74	November 29, 1957	December 6, 1957
Hurricane Dot	93	August 1, 1959	August 8, 1959

TABLE 6. SUMMARY OF HISTORICAL STORM EVENTS SELECTED FOR DEVELOPMENT OF STORM SURGE ELEVATIONS - continued

Name of Storm	**HURDAT ID#**	**Begin Date**	**End Date**
Tropical Storm Maggie	222	August 20, 1970	August 26, 1970
Tropical Storm Diana	250	August 11, 1972	August 19, 1972
Hurricane Iwa	411	November 19, 1982	November 24, 1982
Tropical Storm Gil	418	July 23, 1983	August 4, 1983
Tropical Storm Dalilia	532	July 11, 1989	July 21, 1989
Hurricane Iniki	598	September 5, 1992	September 13, 1992
Tropical Storm Daniel	707	July 23, 2000	August 5, 2000

The ADCIRC model was calibrated by simulating tidal cycles, and then validated by performing storm hindcasts. Tidal calibration is conducted by forcing tides at the open ocean boundaries of the model using known values (Le Provost, 1998), and comparing the simulated water levels to observations over a specific time period or a tidal signal re-synthesized from known tidal constituents. Storm hindcasts are performed upon successful completion of tidal calibrations to evaluate the ability of the model to replicate historical storm events. A wind and pressure field representing a historical storm event is input into the model then resulting water elevations are compared to observed water levels and records. Model validation was performed against Hurricanes Dot and Iniki for this study. Simulated water levels for each event were compared to observed water levels at the NOAA tidal gauge in Nawiliwili harbor which represented the best available data. Results from both events showed agreement with observed storm hydrographs.

The Emprical Simulation Technique (EST) model was used for the stage-frequency analysis. The EST generates a large population of life-cycle databases that are processed to compute mean value frequencies. Input vectors describe the characteristics of each storm such as central pressure and maximum winds. Input vectors for EST analysis included: tidal phase, minimum distance from eye to station, central pressure deficit, maximum winds in hurricane, forward speed of eye of hurricane, and radius to maximum winds. The input response vector was the maximum surge elevation recorded at each station for each storm simulated with ADCIRC. The output is a stage-frequency curve for each station in the study area. The EST model performed a hundred simulations at each station, for a period of 500 years. The mean value was selected from the entire EST simulation population at each station, and the return period elevation is the final resultant value.

Stillwater elevations for the State of Hawaii, obtained using the ADCIRC and EST models, are summarized in Table 7, "Summary of Coastal Stillwater Elevations." Locations of the surge stations are shown in Figure 2. Please note that the station numbers for surge stations do not coincide with the transect numbers.

TABLE 7 - SUMMARY OF COASTAL STILLWATER ELEVATIONS[†]

ISLAND OF KAUAI

FLOODING SOURCE AND LOCATION			ELEVATION (ft Local Tidal Datum)			
STATION	LONGITUDE (NAD83)	LATITUDE	10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
Pacific Ocean						
157	-159.73776	22.11820	0.66	0.79	1.00	2.00
158	-159.74740	22.10420	0.66	0.81	1.04	2.10
159	-159.77948	22.07192	0.66	0.80	1.04	1.95
160	-159.78634	22.06400	0.66	0.77	0.95	1.74
161	-159.78920	22.05303	0.66	0.80	1.01	1.96
162	-159.79037	22.04257	0.66	0.80	1.01	2.01
163	-159.79208	22.03186	0.66	0.80	1.00	1.93
164	-159.79004	22.01538	0.66	0.79	0.98	1.86
165	-159.77890	22.00269	0.66	0.81	1.04	2.11
166	-159.77346	21.99408	0.66	0.81	1.04	2.10
167	-159.76356	21.97673	0.66	0.81	1.03	2.05
168	-159.74352	21.96977	0.66	0.82	1.04	2.11
169	-159.72753	21.96563	0.66	0.82	1.07	2.19
170	-159.70806	21.95739	0.66	0.80	1.02	2.07
171	-159.68770	21.95514	0.66	0.82	1.08	2.33
172	-159.66937	21.94966	0.66	0.82	1.07	2.31
173	-159.65705	21.93847	0.66	0.82	1.06	2.33
174	-159.66154	21.94024	0.66	0.78	1.00	2.12
175	-159.65328	21.93676	0.66	0.82	1.07	2.34
176	-159.65136	21.93058	0.66	0.80	1.02	2.13
177	-159.64658	21.92495	0.66	0.79	1.00	2.04
178	-159.64128	21.92003	0.66	0.80	1.02	2.08
179	-159.63230	21.90888	0.66	0.82	1.05	2.15
180	-159.62123	21.90230	0.66	0.82	1.05	2.14
181	-159.61120	21.89716	0.66	0.81	1.03	2.01
182	-159.60956	21.89310	0.66	0.78	0.97	1.91
183	-159.60155	21.88973	0.66	0.79	1.00	1.92
184	-159.59553	21.89664	0.66	0.83	1.10	2.40
185	-159.59557	21.90017	0.66	0.83	1.11	2.45
186	-159.59212	21.90191	0.66	0.83	1.09	2.42
187	-159.58625	21.89588	0.66	0.84	1.10	2.35
188	-159.58051	21.89465	0.66	0.83	1.07	2.21
189	-159.57709	21.89318	0.66	0.83	1.06	2.18
190	-159.57569	21.89119	0.66	0.82	1.05	2.11
191	-159.57036	21.89173	0.66	0.84	1.08	2.25
192	-159.56238	21.88811	0.66	0.83	1.07	2.21
193	-159.55296	21.88555	0.66	0.82	1.06	2.14
194	-159.53717	21.88444	0.66	0.82	1.06	2.15
195	-159.52764	21.87883	0.66	0.81	1.04	2.02
196	-159.51696	21.88450	0.66	0.84	1.10	2.35
197	-159.50439	21.88539	0.66	0.85	1.13	2.41

[†]These elevations reflect the stillwater elevations associated with the hurricane hazard only. Tsunami hazards may dominate in certain areas.

TABLE 7 - SUMMARY OF COASTAL STILLWATER ELEVATIONS[†] (continued)

ISLAND OF KAUAI

FLOODING SOURCE AND LOCATION			ELEVATION (ft Local Tidal Datum)			
STATION	LONGITUDE (NAD83)	LATITUDE	10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
Pacific Ocean (continued)						
198	-159.49718	21.88219	0.66	0.84	1.10	2.25
199	-159.48147	21.87722	0.66	0.83	1.08	2.16
200	-159.47154	21.87509	0.66	0.84	1.10	2.23
201	-159.46153	21.87253	0.66	0.82	1.06	2.07
202	-159.45484	21.86979	0.66	0.82	1.06	2.05
203	-159.44439	21.86722	0.66	0.78	0.99	1.82
204	-159.43784	21.87069	0.66	0.84	1.10	2.14
205	-159.42910	21.87423	0.66	0.84	1.11	2.18
206	-159.41768	21.88154	0.66	0.83	1.07	2.12
207	-159.41286	21.88595	0.66	0.84	1.11	2.20
208	-159.40463	21.89024	0.66	0.83	1.09	2.12
209	-159.39622	21.90134	0.66	0.85	1.13	2.23
210	-159.38700	21.90220	0.66	0.82	1.04	1.99
211	-159.38705	21.90972	0.66	0.87	1.15	2.31
212	-159.38032	21.91469	0.66	0.86	1.13	2.28
213	-159.37526	21.91948	0.66	0.85	1.12	2.23
214	-159.36827	21.92367	0.66	0.84	1.10	2.14
215	-159.36458	21.92836	0.66	0.85	1.12	2.23
216	-159.35926	21.92987	0.66	0.84	1.09	2.13
217	-159.35387	21.93119	0.66	0.82	1.07	2.02
218	-159.35342	21.93458	0.66	0.84	1.09	2.09
219	-159.34674	21.93711	0.66	0.79	1.02	1.90
220	-159.34828	21.94283	0.66	0.85	1.13	2.18
221	-159.34865	21.94892	0.66	0.86	1.13	2.24
222	-159.35857	21.94872	0.66	0.97	1.49	3.16
223	-159.35684	21.95243	0.66	0.92	1.29	2.74
224	-159.35030	21.95838	0.66	0.86	1.18	2.46
225	-159.34716	21.95467	0.66	0.86	1.14	2.29
226	-159.34065	21.95636	0.66	0.83	1.10	2.18
227	-159.33618	21.95303	0.66	0.82	1.07	2.06
228	-159.32722	21.96385	0.66	0.82	1.07	2.00
229	-159.32980	21.97326	0.66	0.84	1.11	2.01
230	-159.33225	21.98375	0.66	0.85	1.12	2.09
231	-159.32933	21.99336	0.66	0.84	1.10	2.01
232	-159.33904	21.99316	0.66	0.91	1.26	2.43

[†]These elevations reflect the stillwater elevations associated with the hurricane hazard only. Tsunami hazards may dominate in certain areas.

TABLE 7 - SUMMARY OF COASTAL STILLWATER ELEVATIONS† (continued)

ISLAND OF KAUAI

FLOODING SOURCE AND LOCATION			ELEVATION (ft Local Tidal Datum)			
STATION	LONGITUDE (NAD83)	LATITUDE	10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT
Pacific Ocean (continued)						
233	-159.33177	21.99855	0.66	0.84	1.10	2.02
234	-159.33363	22.01358	0.66	0.85	1.12	2.07
235	-159.33661	22.02508	0.66	0.87	1.17	2.23
236	-159.33207	22.03936	0.66	0.84	1.10	2.13
237	-159.33282	22.04706	0.66	0.89	1.21	2.45
238	-159.32681	22.05039	0.66	0.85	1.13	2.23
239	-159.31915	22.05473	0.66	0.83	1.09	2.10
240	-159.31475	22.06486	0.66	0.86	1.13	2.18
241	-159.31349	22.07401	0.66	0.89	1.20	2.36
242	-159.30924	22.07981	0.66	0.85	1.12	2.14
243	-159.30497	22.08528	0.66	0.85	1.12	2.10
244	-159.30260	22.09081	0.66	0.84	1.11	2.08
245	-159.30229	22.09567	0.66	0.87	1.15	2.17
246	-159.29438	22.10273	0.66	0.83	1.08	2.01
247	-159.29362	22.10969	0.66	0.83	1.07	2.00
248	-159.29258	22.11519	0.66	0.85	1.10	2.06
249	-159.29225	22.12001	0.66	0.85	1.10	2.05
250	-159.29144	22.12936	0.66	0.84	1.08	2.03
251	-159.28998	22.13966	0.66	0.82	1.05	1.98
252	-159.29492	22.15039	0.66	0.83	1.09	2.06
253	-159.30241	22.15121	0.66	0.88	1.19	2.33
254	-159.30295	22.15973	0.66	0.84	1.09	2.05
255	-159.30763	22.16457	0.66	0.86	1.16	2.26
256	-159.31167	22.17438	0.66	0.85	1.16	2.26

†These elevations reflect the stillwater elevations associated with the hurricane hazard only. Tsunami hazards may dominate in certain areas.

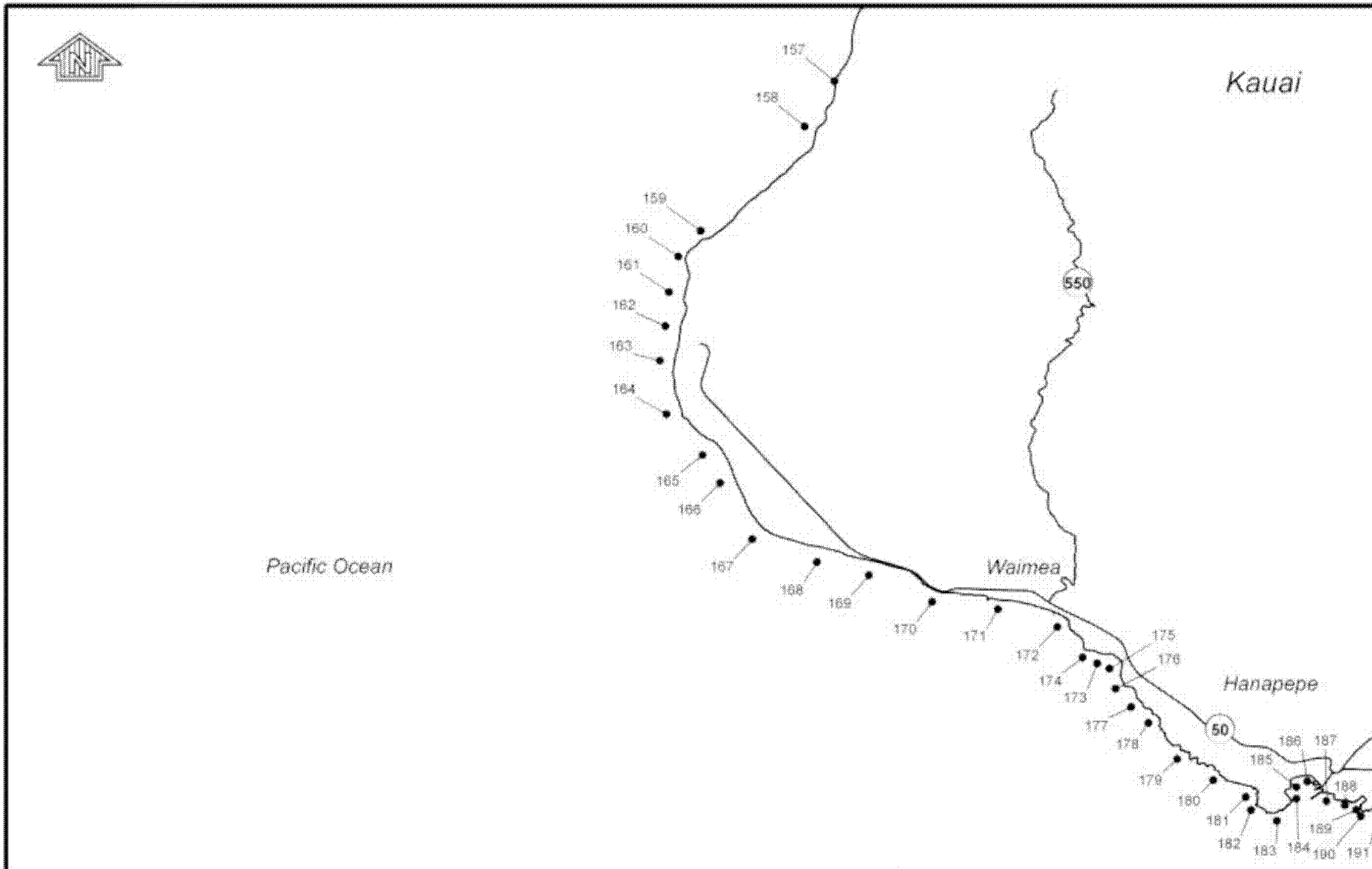


Figure 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

KAUAI COUNTY, HAWAII

ISLAND OF KAUAI

Approximate Scale

0 2 4 8 Miles

STILLWATER STATION LOCATION MAP 1

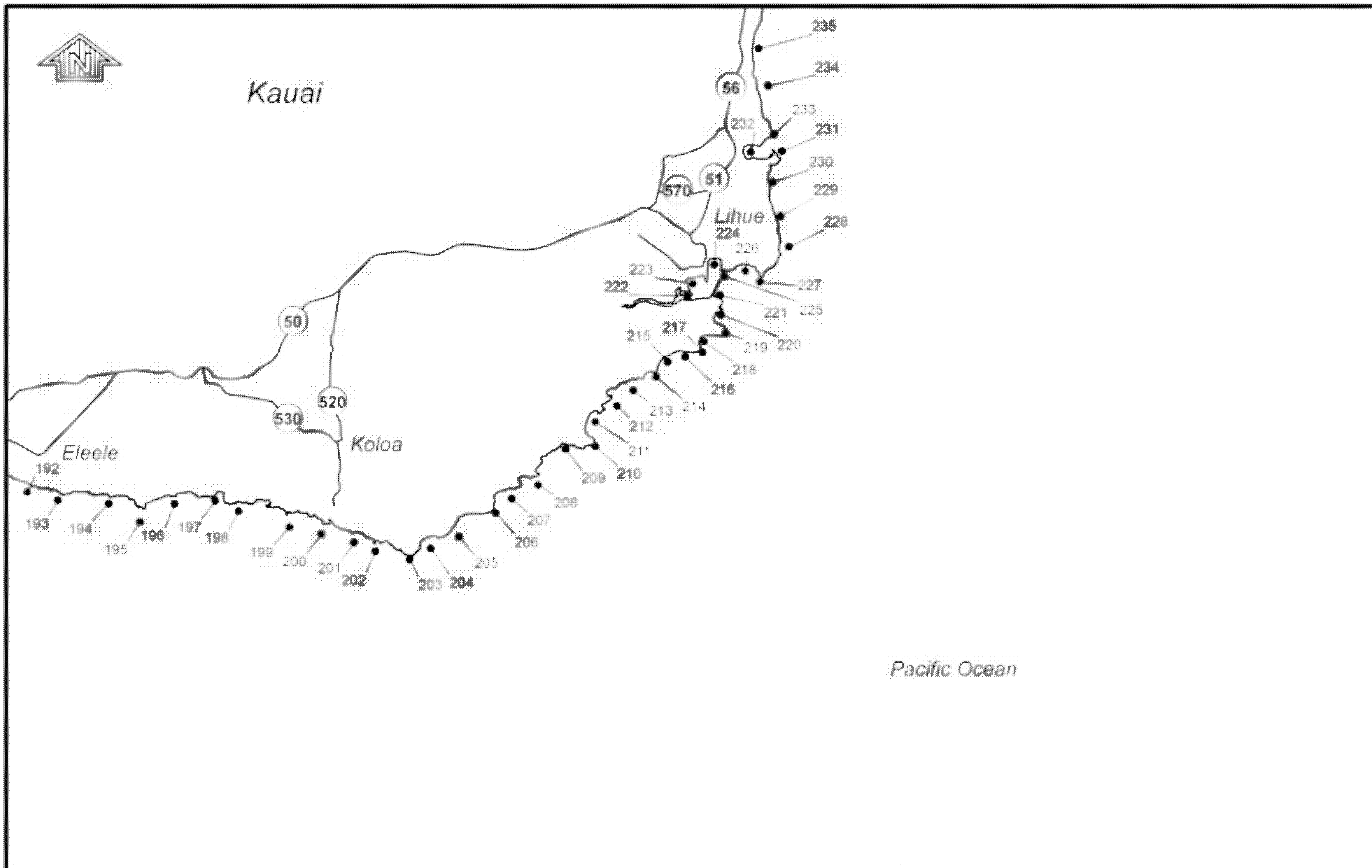


Figure 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

KAUAI COUNTY, HAWAII

ISLAND OF KAUAI

Approximate Scale

0 2 4 8 Miles

STILLWATER STATION LOCATION MAP 2

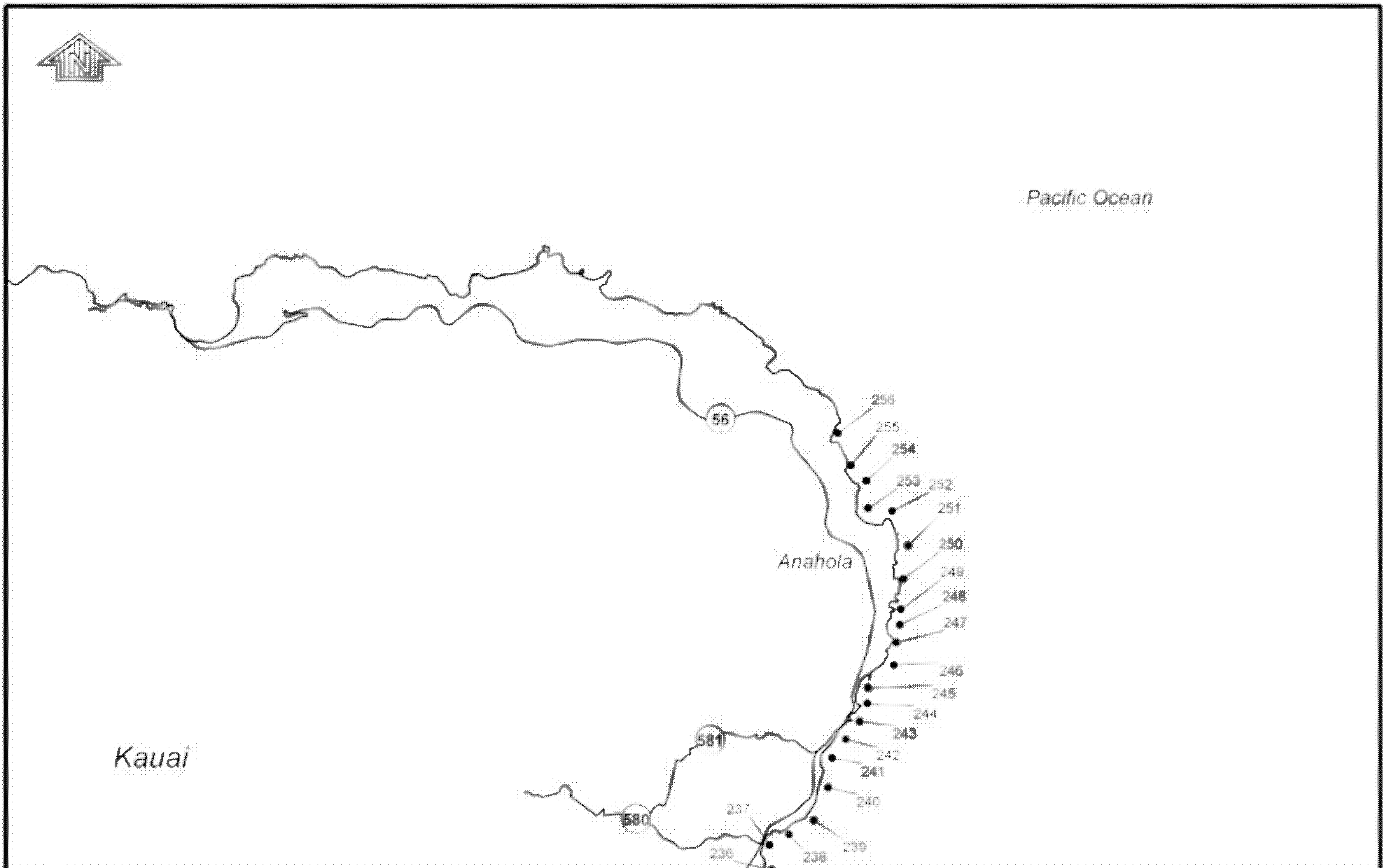


Figure 2

FEDERAL EMERGENCY MANAGEMENT AGENCY

KAUAI COUNTY, HAWAII

ISLAND OF KAUAI

Approximate Scale

0 2 4 8 Miles

STILLWATER STATION LOCATION MAP 3

3.2 Hydraulic Analyses

Analyses of the hydraulic characteristics of flooding from the sources studied were carried out to provide estimates of the elevations of floods of the selected recurrence intervals. Users should be aware that flood elevations shown on the FIRM represent rounded whole-foot elevations and may not exactly reflect the elevations shown on the Flood Profiles or in the Floodway Data tables in the FIS report. For construction and/or floodplain management purposes, users are encouraged to use the flood elevation data presented in this FIS in conjunction with the data shown on the FIRM.

Hydraulic analyses, considering storm characteristics and the shoreline and bathymetric characteristics of the flooding sources studied, were carried out to provide estimates of the elevations of floods of the selected recurrence intervals along each of the shorelines.

Cross sections for the flooding sources studied by detailed methods were obtained from field surveys. All bridges, dams, and culverts were field surveyed to obtain elevation data and structural geometry.

Locations of selected cross sections used in the hydraulic analyses are shown on the Flood Profiles (Exhibit 1). For stream segments for which a floodway was computed (Section 4.2), selected cross-section locations are also shown on the FIRM (Exhibit 2).

Water-surface elevations for floods of the selected recurrence intervals for the streams studied in detail were computed through use of the USACE HEC-2 step-backwater computer program (USACE 1973). The sandbars found at most of the stream mouths at the coastline were assumed to have been washed out before the occurrence of the peak discharge. The selection of the starting water-surface elevations depended on the streamflow condition. For streams discharging into the ocean, the higher of either the mean high tide elevation or the critical-depth elevation at the mouth was used. For inland stream reaches and for tributaries of a stream studied in detail, the normal-depth elevation was used. For streams where the downstream reach was studied in the Flood Insurance Study (FEMA 1981), the elevation from the downstream reach water-surface profile was used.

Cross sections for the backwater analyses of the streams studied in detail were obtained from aerial photogrammetric maps. Bridges, culverts, and stream channel cross sections, including below-water sections, were field surveyed. Cross sections were located at close intervals above and below bridges, culverts, and other hydraulic structures in order to compute the significant backwater effects from these structures.

The photogrammetric maps mentioned previously, and any conditions differ from those just described, are summarized in the paragraphs that follow.

Hanalei Watershed
Aerial photographs were taken in February 1977. Photogrammetric maps were prepared at a scale of 1:4,800, with a contour interval of 5 feet (USACE, 1977). Bridges and stream cross sections were field surveyed in January 1977.

Hydraulic analyses for Hanalei River were performed using the stream flows listed in Table 5, "Summary of Discharges." These analyses were used primarily to determine the changes in the 1-percent annual chance flood elevations caused by the encroachments under consideration. Cross-sectional data were derived from aerial topographic maps and used in HEC-2 computer program models (USACE, 1973, 1977, 1998).

An artificial ocean section located 100 feet downstream from Station 0+00 was added to improve modeling computations at the outlet. In addition, six new cross sections were created to describe the encroachments, and computer interpolated sections were added every 25 feet between cross sections for improved computational accuracy. The encroachments that were analyzed include only the roadway/berm and the U.S. Fish and Wildlife Service (USFWS) Ponds A, B, C, and D.

Contraction and expansion coefficients were adjusted to reflect flow impediments caused by encroachments. Manning's roughness factors used in the 1977 study were adopted for the October 18, 2002, restudy.

Anahola Watershed
Aerial Photographs were taken in February 1977. Photogrammetric maps were prepared at a scale of 1:2,400, with a contour interval of 5 feet (USACE, 1977). Bridges and stream cross sections were field surveyed in October 1977.

Kapaa Watershed
Aerial photographs of Kapaa Stream were compiled in September 1973. Photogrammetric maps were prepared at a scale of 1:2,400, with a contour interval of 5 feet (USACE, 1973). Bridges and stream cross sections were field surveyed in January 1977.

Aerial photographs of Moikeha Canal and Waikaea Canal were taken from September through December 1975. Photogrammetric maps were prepared at a scale of 1:2,400, with a contour interval of 5 feet (Kauai County, 1975). Moikeha Canal improvement plans were used for stream cross section data (Kauai County 1976).

Wailua Watershed
Aerial photographs of the Wailua River were taken from September through December 1975. Photogrammetric maps were prepared at a scale of 1:2,400, with a contour interval of 5 feet (USACE, 1975). Bridges and stream cross sections were field surveyed in 1972 and 1977. The starting water-surface elevations for Opaekaa Stream were determined by the slope/area method (USACE, 1973). Starting water-surface elevations for Kalama Stream were taken at its confluence with Opaekaa Stream, because coincident flow seems likely.

Aerial photographs for Opaekaa Tributary and the upstream reaches of Opaekaa Stream were taken in March 1984. Photogrammetric maps are at a scale of 1:2,400 with a contour interval of 5 feet (USACE, 1984).

Lihue Watershed

Aerial photographs of Nawiliwili Stream and Puali Stream were taken from September through December 1975. Photogrammetric maps were prepared at a scale of 1:2,400, with a contour interval of 5 feet (USACE, 1975). Bridges and stream cross sections were field survey, in October 1977.

Aerial photographs of Huleia and Papakolea Streams were taken from September through December 1975. Photogrammetric maps were prepared at a scale of 1:2,400, with a contour interval of 5 feet (Kauai County, 1975). Additional cross sections for Huleia Stream were field surveyed in March 1984 (USACE, 1984).

Koloa Watershed

Aerial photographs of Waikomo Stream and Omao Stream were taken from September through December 1975. Photogrammetric maps were prepared at a scale of 1:2,400, with a contour interval of 5 feet (USACE, 1975). Bridges and stream cross sections were field surveyed in October 1977. Starting water-surface elevations for Omao Stream were taken from Waikomo Stream, because Omao Stream is the extension of Waikomo Stream.

Aerial photographs of Lawai Stream were taken in March 1984. Photogrammetric maps were prepared at a scale of 1:2,400, with a contour interval of 5 feet (USACE, 1984). Additional cross sections were taken from a bridge plan for the Lauoho Road Bridge (Kauai County, 1928).

Hanapepe Watershed

Aerial photographs of the Hanapepe River were taken in February 1977. Photogrammetric maps were prepared at a scale of 1:2,400, with a contour interval of 5 feet (USACE, 1977). Bridges and stream cross sections were field surveyed in January 1977.

West Kauai Watershed

The Kekaha area is subject to shallow flooding. Numerous streams from the mountains flow into irrigation ditches that drain the flat agricultural lands of the area. The overflow from these ditches produces a sheetflow condition. Aerial photographs of the area were taken in February 1977. Photogrammetric maps were prepared at a scale of 1:4,800, with a contour interval of 5 feet (USACE, 1977). Cross sections were also taken from topographic maps at a scale of 1:4,800, with a contour interval of 1 foot (USDA, 1977), and from a culvert plan for the Kekaha Road Crossing (Kauai County, 1983).

Because of the topography of the area, Kekaha was studied for shallow flooding. Runoff from the hillsides will flow into two basins, one basin upstream and on the Mana side of Kekaha and the other between Kekaha and Waimea, before affecting the developed areas of Kekaha. Runoff from the Waipao, Paua, and

Waiaka Valleys will flow into the upstream basin and runoff from the Kapilimao Valley and four other unnamed valleys will flow into the basin between Kekaha and Waimea.

Outflow discharges from the Waipao-Waiaka basin (the upstream basin) will follow two paths. One path is over a section of Kausmualii Highway on the Mana side and will not affect Kekaha. The two drainage ditch outlets on the Mana side of Kekaha that serve the Waipao-Waiaka basin were assumed to be blocked with sand because the natural sand dune is quite substantial. The other path will flow towards the Kapilimao-Waimea basin and will affect Kekaha. Outflow discharges from the Kapilimao-Waimea basin will flow through the Cox Drainage Ditch (ditch next to Manu Road) and through the drainage ditch that empties near the Kikiaola Small Boat Harbor.

Using the modified Puls routing method, the flood hydrographs were routed through the basins. A backwater analysis was made to determine the flood profile of the overflow discharges affecting Kekaha.

Wainiha Watershed
Aerial photographs of the Wainiha River were taken in September 1973. Photogrammetric maps were prepared at a scale of 1:2,400, with a contour interval of 5 feet (USACE, 1973).

Waimea Watershed
Aerial photographs of the Waimea River were taken in September 1974. Photogrammetric maps were prepared at a scale of 1:2,400, with a contour interval of 5 feet (USACE, 1974).

The revised hydraulic analyses for Hanamaulu Stream, Kalama Stream, and Waikomo Stream were prepared using the USACE HEC-2 hydraulic computer model and aerial topographic mapping at 1"=200' scale, prepared by SHI, dated February 10, 1993. The results of the analyses added detailed flooding information, including a floodway, to the restudied reaches of all three streams.

Channel and overbank roughness factors (Manning's "n" values) used in the hydraulic computations were chosen by engineering judgment and were based on field inspection of the flood plain areas. A listing of roughness coefficients for the channel and overbank areas is given in Table 8.

Hydraulic characteristics for areas of approximate study were calculated by various methods and are grouped into two general categories:

1. Hydraulic characteristics determined by the method described for detailed studies, except that stream cross sections were not field surveyed, and bridges and culverts were not considered.

2. Hydraulic characteristic data extracted from prior studies conducted using criteria similar to those employed for detailed studies.

The hydraulic analyses for this study were based on unobstructed flow. The flood elevations shown on the profiles (Exhibit 1) are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

As a result of this update due to the effects of Hurricane Iniki, the delineations of areas designated as Zones VE, AE, and X from Kekaha to Poipu were revised on the FIRM. Flood inundation elevations inland were computed using toographic mapping at a scale of 1:2,400, prepared for the Kauai County Public Works Department by R. M. Towill Corporation in June 1992 (USACE, 1992), and for the USACE by SHI in November 1992 (Kauai County, 1992).

The procedure used for determining the tsunami runup profile was extracted from a study entitled "Tsunami Inundation Prediction" (Bretschneider and Wybro, 1974) in which a formula was developed for predicting tsunami runup profiles and the calculated results were compared with the recorded inundation data of the 1946 and 1960 tsunami on the islands of Maui and Hawaii. Good to excellent correlations were obtained between the observed and calculated inundation profiles.

Runup elevations are dependent on starting tsunami elevations, inland ground elevations, roughness factors (Manning's "n" values), and expected type of wave behavior (nonbore or bore formation). The derivation of the starting tsunami elevations is discussed in Section 3.1. Topographic maps and the elevation datum used for the tsunami hydraulic analyses were identical to those used for the riverine analyses.

Overland roughness factors used in the hydraulic computations were chosen by engineering judgment and based on field observations of the coastal areas. Most of the coastal areas of Kauai have experienced only the nonbore type of tsunami wave action. The only recorded bore formation in Kauai occurred in 1946 in the Haena area.

The aerial photogrammetric maps that were used to obtain transect profiles for the hydraulic analysis of coastal areas studied in detail from Kekaha to Poipu are summarized as follows:

Waimea and Kekaha area--same maps as used for stream analyses.

Hanapepe--aerial photograph taken in February 1977, photogrammetric maps at a scale of 1:2,400, with a 5-foot contour interval (USACE, 1977).

Kalaheo Gulch to Poipu--aerial photographs taken September through December 1975, Photogrammetric maps at a scale of 1:2,400, with a 5-foot contour interval (Kauai County, 1975).

Flood profiles were drawn showing computed water-surface elevations for floods of the selected recurrence intervals.

Roughness factors (Manning's "n") used in the hydraulic computations were chosen by engineering judgment and were based on field observations of the streams and floodplain areas. Roughness factors for all streams studied by detailed methods are shown in Table 8, "Manning's "n" Values."

TABLE 8 - RANGE OF MANNING'S "n" VALUES

FLOODING SOURCE	CHANNEL "n"	OVERBANK "n"
HANALEI WATERSHED		
Waipa Stream	0.030 – 0.040	0.030 – 0.080
Waioli Stream	0.030	0.040 – 0.090
Hanalei Stream	0.030 – 0.150	0.030 – 0.150
ANAHOLA WATERSHED		
Anahola Stream	0.025 – 0.035	0.040 – 0.070
KAPAA WATERSHED		
Kapaa Stream	0.028 – 0.038	0.032 – 0.070
Moikeha Canal	0.017 – 0.030	0.025 – 0.034
Waikaea Canal	0.023 – 0.036	0.025 – 0.050
WAILUA WATERSHED		
Wailua River	0.030 – 0.045	0.050 – 0.100
Opaekaa Stream	0.020 – 0.050	0.040 – 0.100
Opaekaa Tributary	0.020 – 0.050	0.040 – 0.080
Kalama Stream	0.035 – 0.040	0.038 – 0.080
LIHUE WATERSHED		
Nawiliwili Stream	0.030 – 0.040	0.035 – 0.300
Puali Stream	0.030	0.035 – 0.080
Huleia Stream	0.025 – 0.045	0.025 – 0.070
Papakolea Stream	0.040	0.040 – 0.060
Hanamaulu Stream	0.020	0.030 – 0.080
Hanamaulu Stream Tributary	0.020	0.040
KOLOA WATERSHED		
Waikomo	0.030 – 0.040	0.040 – 0.100
Omao Stream	0.040 – 0.050	0.070 – 0.080
Lawai Stream	0.040 – 0.050	0.040 – 0.080
HANAPEPE WATERSHED		
Hanapepe River	0.025	0.100
WEST KAUAI WATERSHED		
Kekaha Drainageway	0.050 – 0.080	0.060 – 0.100

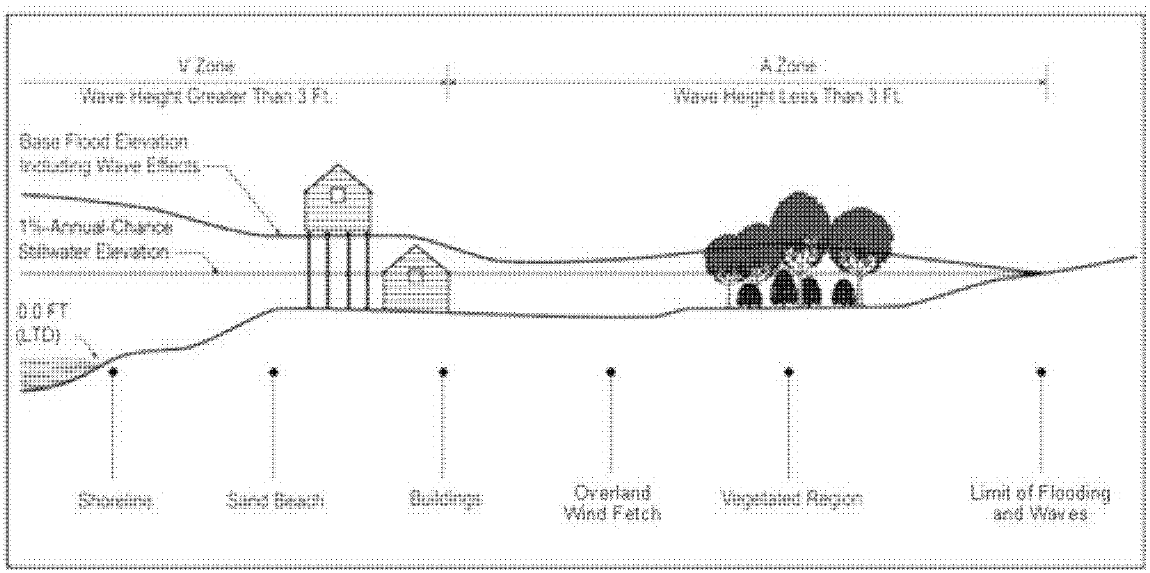
TABLE 8 - RANGE OF MANNING'S "n" VALUES - continued

FLOODING SOURCE	CHANNEL "n"	OVERBANK "n"
WAINIHA WATERSHED		
Wainiha River	0.025 – 0.045	0.030 – 0.080
WAIMEA WATERSHED		
Waimea River	0.025 – 0.040	0.040 – 0.080

The hydraulic analyses for this FIS were based on unobstructed flow. The flood elevations shown on the profiles are thus considered valid only if hydraulic structures remain unobstructed, operate properly, and do not fail.

Areas of coastline subject to significant wave attack are referred to as coastal high hazard zones. The USACE has established the 3.0-foot breaking wave as the criterion for identifying the limit of coastal high hazard zones (USACE, 1975). The 3.0-foot wave has been determined as the minimum size wave capable of causing major damage to conventional wood frame and brick veneer structures.

Figure 3 illustrates a profile for a typical transects along with the effects of energy dissipation and regeneration on a wave as it moves inland. This figure shows the wave crest elevations being decreased by obstructions, such as buildings, vegetation, and rising ground elevations, and being increased by open, unobstructed wind fetches. Figure 3 also illustrates the relationship between the local still water elevation, the ground profile and the location of the Zone V/A boundary. This inland limit of the coastal high hazard area is delineated to ensure that adequate insurance rates apply and appropriate construction standards are imposed, should local agencies permit building in this coastal high hazard area.



TRANSECT SCHEMATIC Figure 3

Deepwater wave characteristics associated to the 100-year storm were developed using the hurricane prediction technique for slowly moving hurricanes as described in the Shore Protection Manual (USACE, 1984). The wave conditions are calculated based on hurricane parameters, such as central pressure deficit, forward translation speed, radius to maximum winds and maximum sustained speed. In particular for the Hawaiian Islands, Hurricane Iniki's parameters from the HURDAT database (1992) were utilized for the application of the prediction technique. FEMA guidelines for V Zone mapping define H_s as the significant wave height or the average over the highest one third of waves and T_s as the significant wave period associated with the significant wave height. Mean wave conditions are described as:

$$\overline{H} = H_s \times 0.626$$
$$\overline{T} = T_s \times 0.85$$

where $\overline{H}$ is the average wave height of all waves and $\overline{T}$ is the average wave period.

The transects were located with consideration given to the physical and cultural characteristics of the land so that they would closely represent conditions in their locality. Transects were spaced close together in areas of complex topography and dense development. In areas having more uniform characteristics, the transects were spaced at larger intervals. It was also necessary to locate transects in areas where unique flooding existed and in areas where computed wave heights varied significantly between adjacent transects. Transects are shown on each FIRM panel.

The transect profiles were obtained using bathymetric and topographic data from various sources. The greater part of the bathymetric data set was comprised of 255 individual surveys NOAA NOS hydrographic surveys, collected from 1900 to 2005. Soundings were originally in the mean lower low water (MLLW) or mean low water (MLW) datums. Relative datum differences were retrieved for NOS water level gages in the Hawaiian Islands, and an average conversion factor was determined for each datum (0.08 m decrease from MLW to MLLW, and 0.8 m increase in depth from MLLW to Local Tidal Datum). JALBTCX provided bathymetric LiDAR for the six islands. This dataset was collected in 1999 and 2000, and provided high-resolution coverage of the nearshore bathymetry surrounding the islands. Depths were adjusted from the MLLW datum to Local Tidal Datum and merged with the NOAA dataset. The USACE Honolulu District provided a 2004 hydrographic survey of Honolulu Harbor. Depths were adjusted from MLLW to Local Tidal Datum and merged into the comprehensive dataset. A 2004 multibeam survey of Pearl Harbor conducted by the U.S. Navy was provided by the NOAA National Geophysical Data Center. Depths were converted from MLLW to Local Tidal Datum and merged into the dataset. Once all datasets were assembled, overlapping data was removed to leave the best possible data in the nearshore areas of the islands. The topographic portion of the transect profiles was populated from LiDAR. These data were collected for floodplain mapping along the southern coasts of the six islands included in the study and extends from the shoreline to the approximate 10 meter contour. The LiDAR data were collected in fall 2006, post-processed to bare earth and quality controlled to meet FEMA mapping standards. LiDAR elevations were delivered in the Local Tidal Datum, therefore no conversion was necessary.

Beach erosion was applied as per standard FEMA (2003) and FEMA (2007) Guidelines and Specifications for Flood Hazard Mapping Partners methodology and VE Zone were mapped up to the extent of the Primary Frontal Dune (PFD).

Nearshore wave-induced processes, such as wave setup and wave runup, constitute a greater part of the combined wave envelope than storm surge due to the islands' high cliffs and location exposed to ocean waves. For this particular environment, the Direct Integrated Method (FEMA, 2007) was used to determine wave setup along the coastline.

Offshore coral reefs surround Hawaii and produce localized variation in wave setup values. A modified wave setup approach was applied in those locations where reefs extend above the breaking depth of the incident wave height. The criterion applied was based upon the methodology outlined by Gourlay (1996).

Wave height calculation used in this study follows the methodology described in the FEMA (2003) and the FEMA (2007) Guidelines and Specifications for Flood Hazard Mapping Partners.

RUNUP 2.0 was used to predict wave runup value on natural shore then adjusted to follow the FEMA (2005) "Procedural Memorandum No. 37" that recommends the use of the 2-percent wave runup for determining base flood elevations. For steep cliffs and in areas dominated by coral reefs, wave runup was determined using the Technical Advisory Committee for Water Retaining Structures (TAW) method (van der Meer, 2002). In presence of shore-protection structures, wave runup calculations were computed using the appropriate roughness coefficient for the structure. The Shore Protection Manual (SPM) Method was applied in cases of wave runup on vertical structures. For wave run-up at the crest of a slope that transitions to a plateau or downslope, run-up values were determined using the "Methodology for wave run-up on a hypothetical slope" as described in the FEMA (2003) and the FEMA (2007) Guidelines and Specifications for Flood Hazard Mapping Partners.

Figure 4, "Transect Location Map," illustrates the location of each transect. Along each transect, wave envelopes were computed considering the combined effects of changes in ground elevation, vegetation and physical features. Between transects, elevations were interpolated using topographic maps, land-use and land-cover data, and engineering judgment to determine the aerial extent of flooding. The results of the calculations are accurate until local topography, vegetation, or cultural development within the community undergo major changes. The transect data for the three islands are presented in Table 9, "Transect Descriptions," which describes the location of each transect. In addition, Table 9, provides the 1-percent annual chance stillwater, wave setup and maximum wave crest elevations for each transect along the island coastline. In Table 10, "Transect Data," the flood hazard zone and base flood elevations for each transect flooding source is provided, along with the 10-, 2-, 1-, and 0.2-percent annual chance stillwater elevations for the respective flooding source.

Previous mapping of the tsunami hazard was merged with the detailed hurricane coastal hazard study in this revision. This was accomplished by comparing the zone type, base flood elevation, and inland flooding extent of coincident tsunami and hurricane storm surge hazards. The higher of the two elevations was retained and presented on the Flood Insurance Rate Map. If in a tsunami hazard-dominated area, the inland limit of the hurricane storm surge flooding extends further landward than the tsunami hazard, the Tsunami base flood elevation is show and the flooding extent is extended to where the hurricane hazard is mapped. This is to reflect the increased hazard generated by the use of updated topographic data. The VE Zone was extended and mapped to the inland limit of the Primary Frontal Dune for both tsunami and hurricane hazards. In cases where elevations were similar, engineering judgment was applied to facilitate the most appropriate representation of the higher hazard.

Users of the FIRM should also be aware that coastal flood elevations are provided in the Summary of Stillwater Elevations table (Table 7) in this report. If the elevation on the FIRM is higher than the elevation shown in this table, a wave height, wave runup, and/or wave setup component likely exists, in which case, the higher elevation should be used for construction and/or floodplain management purposes.

As defined in the July 1989 *Guidelines and Specifications for Wave Elevation Determination and V Zone Mapping,* the coastal high hazard area (Zone VE) is the area where wave action and/or high velocity water can cause structural damage (*Guidelines and Specifications for Wave Elevation Determination and V-Zone Mapping*, FEMA, 1989). It is designated on the FIRM as the most landward of the following three points:

1) The point where the 3.0 ft or greater wave height could occur;
2) The point where the eroded ground profile is 3.0 ft or more below the maximum runup elevation; and
3) The primary frontal dune as defined in the NFIP regulations.

These three points are used to locate the inland limit of the coastal high hazard area to ensure that adequate insurance rates apply and appropriate construction standards are imposed, should local agencies permit building in this area.

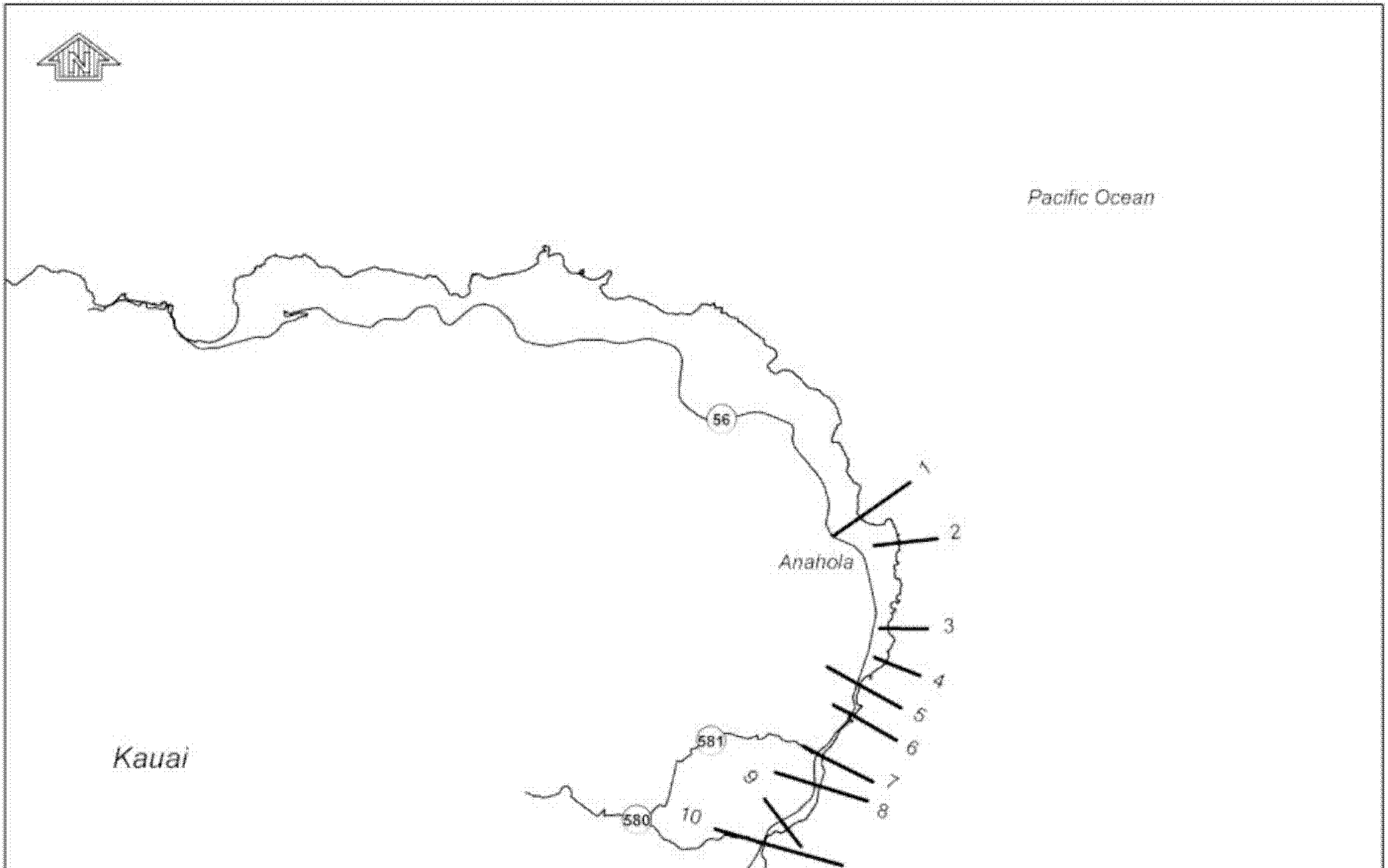


Figure 4

FEDERAL EMERGENCY MANAGEMENT AGENCY

KAUAI COUNTY, HAWAII

ISLAND OF KAUAI

Approximate Scale

0 2 4 8 Miles

TRANSECT LOCATION MAP 1

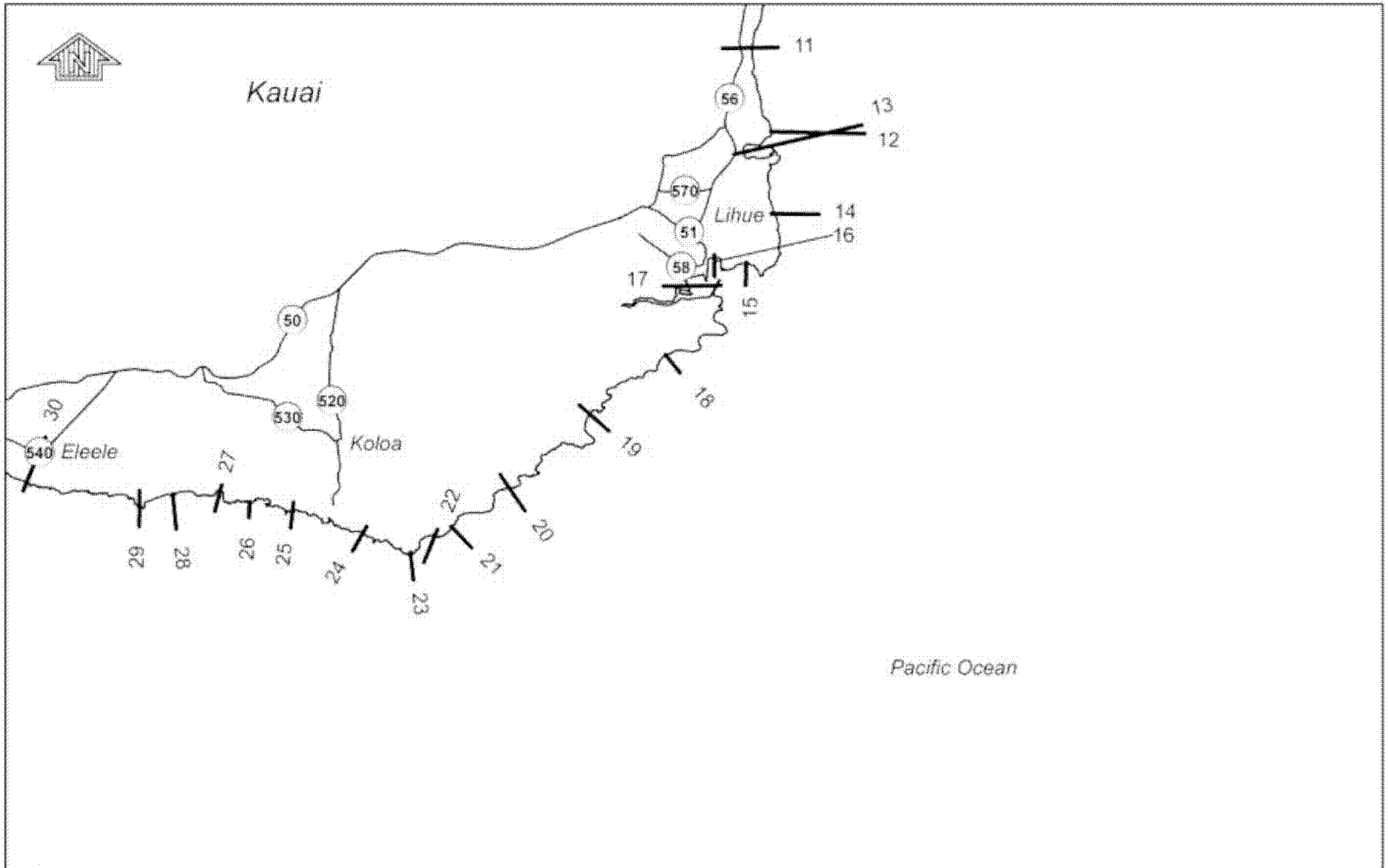


Figure 4

FEDERAL EMERGENCY MANAGEMENT AGENCY

KAUAI COUNTY, HAWAII

ISLAND OF KAUAI

Approximate Scale

0 2 4 8 Miles

TRANSECT LOCATION MAP 2

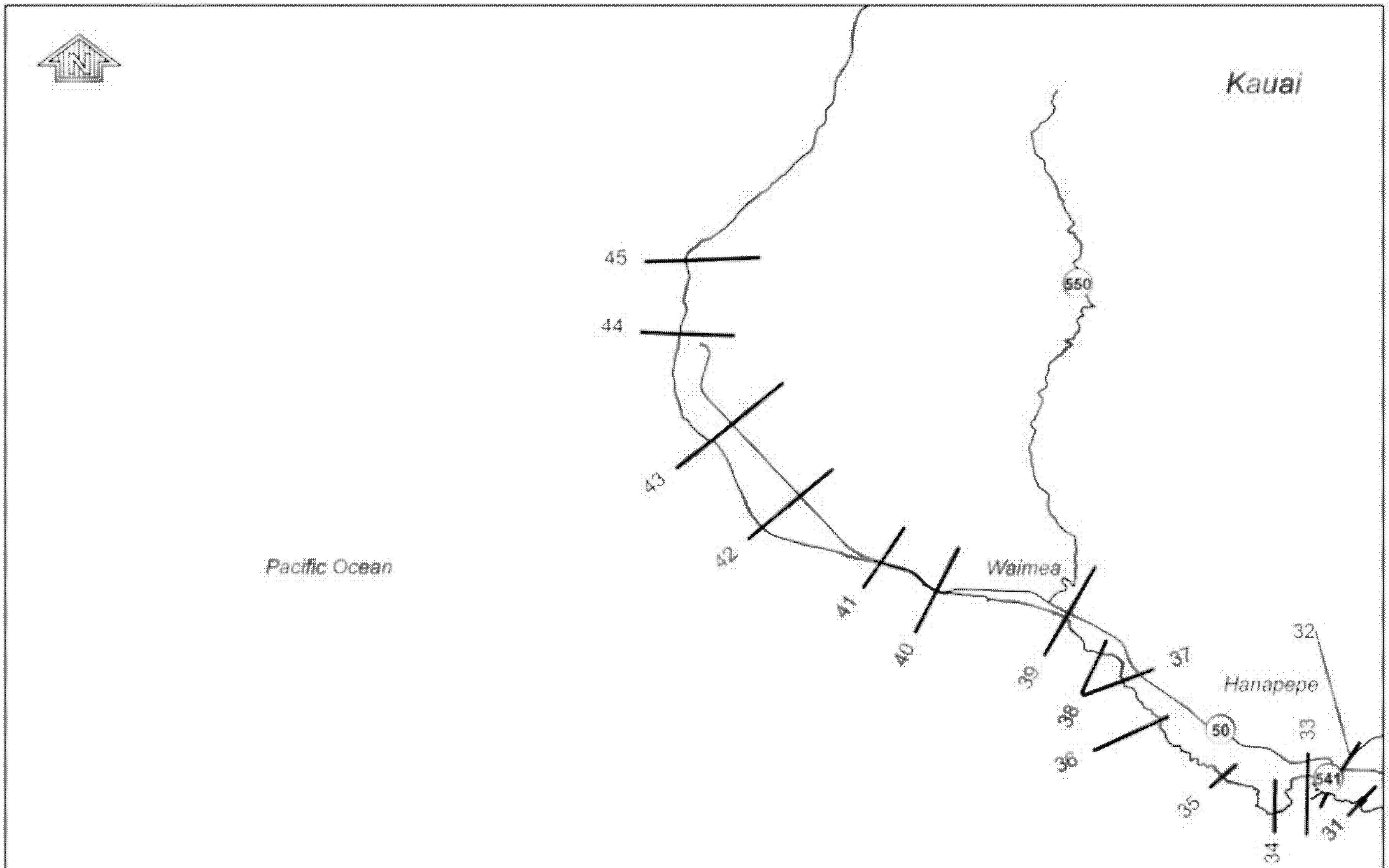


Figure 4

FEDERAL EMERGENCY MANAGEMENT AGENCY

KAUAI COUNTY, HAWAII

ISLAND OF KAUAI

Approximate Scale

0 2 4 8 Miles

TRANSECT LOCATION MAP 3

TABLE 9 - TRANSECT DESCRIPTIONS†

Island of Kauai

TRANSECT	LOCATION	ELEVATION (feet Local Tidal Datum) 1-PERCENT ANNUAL CHANCE STILLWATER	WAVE SETUP	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST
1	On the Pacific Ocean coastline, on the northeast side of the island, approximately 1,820 feet northeast of the intersection of Anahola Road and Kamane Road, located in Anahola, at N 22.148309°, W 159.305502°.	1.2	3.0	6.5
2	On the Pacific Ocean coastline, on the northeast side of the island, approximately 0.60 mile northeast of the intersection of Ehukai Road and Mahuahua Road, located east of the Hawaiian Homesteads subdivision, at N 22.140688°, W 159.293288°.	1.1	6.0	10.8
3	On the Pacific Ocean coastline, on the east side of the island, approximately 1,630 feet northeast of the intersection of Kapoli Street and Makanani Street, located in Kumukumu, at N 22.114216°, W 159.296666°.	1.1	4.5	8.6
4	On the Pacific Ocean coastline, on the east side of the island, approximately 0.426 mile east-northeast of the intersection of Kamole Road and Kuhio Highway (Hwy 56), located in Kumukumu, at N 22.10387°, W 159.297421°.	1.1	4.7	13.4[1]
5	On the Pacific Ocean coastline, on the east side of the island, approximately 640 feet south of Kealia Road and Kuhio Highway (Hwy 56), located northeast of Kapaa , at N 22.09684°, W 159.305574°.	1.1	4.3	8.4
6	On the Pacific Ocean coastline, on the east side of the island, approximately 1,910 feet south of the intersection of Mailihuna Road and Kuhio Highway (Hwy 56), located in Kapaa, at N 22.087652°, W 159.307927°.	1.1	4.4	8.5
7	On the Pacific Ocean coastline, on the east side of the island, approximately 660 feet southeast of the intersection of Huluili Street and Kukui Street, located in Kapaa, at N 22.074744°, W 159.317093°.	1.2	6.2	11.4
8	On the Pacific Ocean coastline, on the east side of the island, approximately 170 feet northeast of the intersection of Keaka Road and Moanakai Road, located in Kapaa, at N 22.065523°, W 159.317789°.	1.1	6.2	11.3

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Wave runup elevation

TABLE 9 - TRANSECT DESCRIPTIONS – continued†

Island of Kauai

TRANSECT	LOCATION	ELEVATION (feet Local Tidal Datum) 1-PERCENT ANNUAL CHANCE STILLWATER	WAVE SETUP	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST
8	On the Pacific Ocean coastline, on the east side of the island, approximately 170 feet northeast of the intersection of Keaka Road and Moanakai Road, located in Kapaa, at N 22.065523°, W 159.317789°.	1.1	6.2	11.3
9	On the Pacific Ocean coastline, on the east side of the island, approximately 1,780 feet southeast of the intersection of Kapaa Bypass and Kuhio Highway (Hwy 56), located in Papaloa, at N 22.052223°, W 159.327673°.	1.1	6.2	11.3
10	On the Pacific Ocean coastline, on the east side of the island, approximately 330 feet northeast of the intersection of Kuamoo Road and Kuhio Highway (Hwy 56), located in Wailua, at N 22.047859°, W 159.334958°.	1.2	6.4	11.6
11	On the Pacific Ocean coastline, on the east side of the island, approximately 0.676 mile northeast of the intersection of Marine Camp Road and Kuhio Highway (Hwy 56), located in the Wailua County Golf Course, at N 22.025015°, W 159.338714°.	1.2	6.4	11.5
12	On the Pacific Ocean coastline, on the east side of the island, approximately 0.808 mile northeast of the intersection of Hehi Road and Kuhio Highway (Hwy 56), located east of Hanamaulu, at N 21.999066°, W 159.332543°.	1.1	6.9	12.2
13	On the Pacific Ocean coastline, on the east side of the island, approximately 970 feet southeast of the intersection of Hehi Road and Kuhio Highway (Hwy 56), located in east of Hanamaulu, at N 21.992838°, W 159.341168°.	1.3	4.4	8.7
14	On the Pacific Ocean coastline, on the east side of the island, approximately 0.934 mile south of the intersection of Ahukini Road and a north / south road that lies between the coastline and a runway, located at Lihue Airport, at N 21.973789°, W 159.331521°.	1.1	4.8	13.9[1]
15	On the Pacific Ocean coastline, on the southeast side of the island, approximately 680 feet south of the cul de sac at the end of Hoolaulea Way, located near Nawiliwili, at N 21.958429°, W 159.340484°.	1.1	4.3	8.3

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Wave runup elevation

TABLE 9 - TRANSECT DESCRIPTIONS – continued†

Island of Kauai

TRANSECT	LOCATION	ELEVATION (feet Local Tidal Datum) 1-PERCENT ANNUAL CHANCE STILLWATER	WAVE SETUP	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST
16	On the Pacific Ocean coastline, on the southeast side of the island, approximately 1,930 feet northeast of the intersection of Rice Street and Lanoa Street, located near Nawiliwili, at N 21.960518°, W 159.350263°.	1.2	4.2	8.3
17	On the Pacific Ocean coastline, on the southeast side of the island, approximately 540 feet north of the boat launch at the southeast corner of the harbor, located in Niumalu, at N 21.951534°, W 159.358194°.	1.5	0.8	7.2[1]
18	On the Pacific Ocean coastline, on the southeast side of the island, approximately 1.39 feet northeast of Kuahonu Point, located in Kauai County, at N 21.929961°, W 159.365185°.	1.1	5.0	15.5[1]
19	On the Pacific Ocean coastline, on the southeast side of the island, approximately 0.583 mile northeast of Kuahonu Point, located in Kauai County, at N 21.912185°, W 159.389008°.	1.1	4.8	9.2
20	On the Pacific Ocean coastline, on the southeast side of the island, approximately 460 feet south of the intersection of two private roads, located on the peninsula southeast of Kawailoa Bay in Kauai County, at N 21.889306°, W 159.413709°.	1.1	4.5	8.6
21	On the Pacific Ocean coastline, on the southeast side of the island, approximately 0.441 mile east southeast of the intersection of Poipu Road and the road at the south end of Poipu Bay Resort Golf Course, located east of Poipu, at N 21.876987°, W 159.431356°.	1.1	4.5	8.6
22	On the Pacific Ocean coastline, on the southeast side of the island, approximately 1,590 feet south southeast of the intersection of Poipu Road and the road at the south end of Poipu Bay Resort Golf Course, located east of Poipu, at N 21.874606°, W 159.436314°.	1.1	4.4	8.5
23	On the Pacific Ocean coastline, on the south side of the island, approximately 0.542 mile south southeast of the intersection of Poipu Road and Ala Kinoiki, located in Poipu at the southern extremity of the island of Kauai, at N 21.868466°, W 159.443987°.	1.0	5.0	23.0[1]

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Wave runup elevation

TABLE 9 - TRANSECT DESCRIPTIONS – continued[†]

Island of Kauai

TRANSECT	LOCATION	ELEVATION (feet Local Tidal Datum) 1-PERCENT ANNUAL CHANCE STILLWATER	WAVE SETUP	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST
24	On the Pacific Ocean coastline, on the south side of the island, approximately 1,960 feet east-southeast of the intersection of Hoonani Road and Kapili Road, located in Poipu, at N 21.87523°, W 159.458636°.	1.1	4.1	7.9
25	On the Pacific Ocean coastline, on the south side of the island, approximately 0.384 mile east southeast of the intersection of Lawai Road and Ami Road, located in Kukuiula, at N 21.881807°, W 159.480463°.	1.1	3.9	7.6
26	On the Pacific Ocean coastline, on the south side of the island, approximately 370 feet southwest of the eastern entrance to the parking lot of Spouting Horn Beach Park, at N 21.884472°, W 159.493644°.	1.1	5.1	9.6
27	On the Pacific Ocean coastline, on the south side of the island, approximately 350 feet southwest of the east end of Lawai Road, located at Lawai Bay, at N 21.888664°, W 159.502576°.	1.1	4.2	8.1
28	On the Pacific Ocean coastline, on the south side of the island, approximately 220 feet east southeast of a 90° bend in a farm road, located midway between Nomilo Fishpond and Lawai Bay, at N 21.886973°, W 159.517346°.	1.1	4.0	13.1[1]
29	On the Pacific Ocean coastline, on the south side of the island, approximately 320 feet southwest of the end of a farm (private) road that runs along the east shore of Nomilo Fishpond, located approximately 520 feet northeast of at Makaokahai Point, at N 21.883622°, W 159.527628°.	1.0	4.6	8.6
30	On the Pacific Ocean coastline, on the south side of the island, approximately 0.814 mile southwest of the intersection of Halewili Road and McBride New Mill Road, located in Numila, at N 21.890964°, W 159.562394°.	1.1	5.5	47.0[1]
31	On the Pacific Ocean coastline, on the south side of the island, approximately 530 feet north northwest of the intersection of two farm roads that meet on the shore of Wahiawa Bay, located midway between Eleele and Numila, at N 21.897062°, W 159.574768°.	1.0	4.3	8.2

[†]All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Wave runup elevation

TABLE 9 - TRANSECT DESCRIPTIONS – continued†

Island of Kauai

TRANSECT	LOCATION	ELEVATION (feet Local Tidal Datum) 1-PERCENT ANNUAL CHANCE STILLWATER	WAVE SETUP	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST
33	On the Pacific Ocean coastline, on the south side of the island, approximately 1,660 feet south of the intersection of Kaumualii Highway (Hwy 50) and Puolo Rd, located in Hanapepe, at N 21.903887°, W 159.59238°.	1.1	3.9	7.7
34	On the Pacific Ocean coastline, on the southwest side of the island, approximately 700 feet east of Puolo Point, located south of the Port Allen Airport, at N 21.892446°, W 159.602433°.	1.0	4.9	9.0
35	On the Pacific Ocean coastline, on the southwest side of the island, approximately 0.718 mile south southeast of the intersection of the NE/SW road running through the housing development with a farm (private) road running along the southwest edge of the development, located in Kaumakani, at N 21.903681°, W 159.618607°.	1.0	4.6	8.9[1]
36	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1.04 miles south southeast of the intersection of Kaumualii Highway (Hwy 50) and the road to Pakala Village, located about midway between Pakala Village and Kaumakani, at N 21.921049°, W 159.637969°.	1.0	4.1	7.9
37	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1,930 feet west southwest of the intersection of Kaumualii Highway (Hwy 50) and the road to Pakala Village, located in Pakala Village, at N 21.933164°, W 159.649404°.	1.0	4.1	7.9
38	On the Pacific Ocean coastline, on the southwest side of the island, approximately 0.840 mile southeast of the entrance of Russian Fort Elizabeth State Historical Park, located southeast of Waimea, at N 21.941963°, W 159.656063°.	1.1	4.1	7.9
39	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1,510 feet west of Russian Fort Elizabeth State Historical Park, located in Waimea, at N 21.952412°, W 159.667093°.	1.1	4.1	8.0

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Wave runup elevation

TABLE 9 - TRANSECT DESCRIPTIONS – continued[†]

Island of Kauai

TRANSECT	LOCATION	ELEVATION (feet Local Tidal Datum) 1-PERCENT ANNUAL CHANCE STILLWATER	WAVE SETUP	MAXIMUM 1-PERCENT ANNUAL CHANCE WAVE CREST
40	On the Pacific Ocean coastline, on the southwest side of the island, approximately 220 feet west of the intersection of Kaumualii Highway (Hwy 50) and Aukuu Road, located in Kekaha, at N 21.961098°, W 159.706721°.	1.0	4.1	7.9
41	On the Pacific Ocean coastline, on the southwest side of the island, approximately 330 feet east southeast of the intersection of Kaumualii Highway (Hwy 50) and Akialoa Road, located in Kekaha, at N 21.969796°, W 159.723915°.	1.1	4.1	7.9
42	On the Pacific Ocean coastline, on the southwest side of the island, approximately 1,760 feet southwest of the intersection of south Sidewinder Road and Kokole Point Road, located at the south end of the Pacific Missile Range Facility, at N 21.980728°, W 159.760523°.	1.0	4.6	8.6
43	On the Pacific Ocean coastline, on the west side of the island, approximately 1,280 feet south of the intersection of Kia Road and north Sidewinder Road, located at the Pacific Missile Range Facility, at N 22.007118°, W 159.776499°.	1.0	4.3	8.3
44	On the Pacific Ocean coastline, on the west side of the island, approximately 0.422 mile northwest of the intersection of Kao Road and Nohili Road, located at the Pacific Missile Range Facility, at N 22.040458°, W 159.785833°.	1.0	4.6	8.6
45	On the Pacific Ocean coastline, on the west side of the island, approximately 0.713 mile southwest of the end north end of Nohili Road, located at the Pacific Missile Range Facility, at N 22.063144°, W 159.784084°.	1.0	4.6	8.5

[†]All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.

TABLE 10 - TRANSECT DATA†

FLOODING SOURCE	TRANSECT	STILLWATER ELEVATION (feet Local Tidal Datum) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT	ZONE	BASE FLOOD ELEVATION (feet Local Tidal Datum)
			Kauai County				
Pacific Ocean	1	0.7	0.9	4.2[1]	2.3	VE	6
		0.7	0.9	1.2	2.3	AE	6[2]
Pacific Ocean	2	0.7	0.8	7.0[1]	2.0	VE	9-11
						AE	7-9
Pacific Ocean	3	0.7	0.8	5.6[1]	2.0	VE	8-9
						AE	8
		0.7	0.8	1.1	2.0	AE	7[2]
Pacific Ocean	4	0.7	0.8	1.1	2.0	VE	13[2]
						AE	13[2]
Pacific Ocean	5	0.7	0.9	5.5[1]	2.2	VE	8
						AE	7-8
		0.7	0.9	1.1	2.2	AE	6[2]
Pacific Ocean	6	0.7	0.9	5.6[1]	2.1	VE	8-9
						AE	6-8
Pacific Ocean	7	0.7	0.9	7.4[1]	2.3	VE	10-11
						AE	10
		0.7	0.9	1.2	2.3	AE	9[2]
Pacific Ocean	8	0.7	0.8	7.4[1]	2.2	VE	9-11
						AE	7-9
Pacific Ocean	9	0.7	0.8	7.4[1]	2.2	VE	9-11
		0.7	0.8	1.1	2.2	AE	9[2]
Pacific Ocean	10	0.7	0.9	7.6[1]	2.4	VE	10-12
						AE	8-10
Pacific Ocean	11	0.7	0.9	7.5[1]	2.2	VE	10-12
						AE	8-10
Pacific Ocean	12	0.7	0.8	8.0[1]	2.0	VE	12
		0.7	0.8	1.1	2.0	VE	112
						AE	112

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Includes wave setup
[2]Wave runup elevation

TABLE 10 - TRANSECT DATA† - continued

FLOODING SOURCE	TRANSECT	STILLWATER ELEVATION (feet Local Tidal Datum) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT	ZONE	BASE FLOOD ELEVATION (feet Local Tidal Datum)
				Kauai County - continued			
Pacific Ocean	13	0.7	0.9	5.7[1]	2.4	VE	8-9
						AE	6-8
Pacific Ocean	14	0.7	0.9	1.1	2.0	VE	14[2]
						AE	14[2]
Pacific Ocean	15	0.7	0.8	5.4[1]	2.2	VE	8
						AE	7-8
		0.7	0.8	1.1	2.2	AE	6[2]
Pacific Ocean	16	0.7	0.9	5.4[1]	2.5	VE	7-8
						AE	5-7
Pacific Ocean	17	0.7	1.0	1.5	3.1	VE	7[2]
						AE	7[2]
Pacific Ocean	18	0.7	0.8	1.1	2.2	VE	16[2]
						AE	16[2]
Pacific Ocean	19	0.7	0.9	6.0[1]	2.3	VE	8-9
						AE	8
		0.7	0.9	1.1	2.3	AE	7[2]
Pacific Ocean	20	0.7	0.8	5.6[1]	2.2	VE	8-9
						AE	6-8
Pacific Ocean	21	0.7	0.9	5.6[1]	2.2	VE	8-9
						AE	6-8
Pacific Ocean	22	0.7	0.9	5.5[1]	2.1	VE	8
		0.7	0.9	1.1	2.1	AE	8[2]
Pacific Ocean	23	0.7	0.8	1.0	1.8	VE	23[2]
						AE	23[2]
Pacific Ocean	24	0.7	0.8	5.1[1]	2.1	VE	7-8
						AE	7
		0.7	0.8	1.1	2.1	AE	6[2]

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Includes wave setup
[2]Wave runup elevation

TABLE 10 - TRANSECT DATA[†] - continued

FLOODING SOURCE	TRANSECT	STILLWATER ELEVATION (feet Local Tidal Datum) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT	ZONE	BASE FLOOD ELEVATION (feet Local Tidal Datum)
Kauai County - continued							
Pacific Ocean	25	0.7	0.8	4.9[1]	2.2	VE	8
		0.7	0.8	1.1	2.2	AE	7[2]
Pacific Ocean	26	0.7	0.8	6.2[1]	2.2	VE	10
		0.7	0.8	1.1	2.2	VE	9[2]
						AE	9[2]
Pacific Ocean	27	0.7	0.9	5.3[1]	2.4	VE	7-8
						AE	5-7
Pacific Ocean	28	0.7	0.8	1.1	2.3	VE	13[2]
						AE	13[2]
Pacific Ocean	29	0.7	0.8	5.6[1]	2.0	VE	8-9
						AE	6-8
		0.7	0.8	5.2[1]	2.0	AE	5
Pacific Ocean	30	0.7	0.8	1.1	2.2	VE	47[2]
						AE	47[2]
Pacific Ocean	31	0.7	0.8	5.3[1]	2.2	VE	7-8
						AE	5-7
Pacific Ocean	32	0.7	0.8	5.6[1]	2.3	VE	8-9
						AE	8
		0.7	0.8	1.1	2.3	AE	7[2]
Pacific Ocean	33	0.7	0.8	5.0[1]	2.4	VE	7-8
						AE	5-7
Pacific Ocean	34	0.7	0.8	5.91	1.9	VE	8-9
						AE	7-8
		0.7	0.8	1.0	1.9	AE	6[2]
Pacific Ocean	35	0.7	0.8	1.1	2.1	VE	9[2]
						AE	9[2]
Pacific Ocean	36	0.7	0.8	5.1[1]	2.1	VE	7-8
						AE	5-7
Pacific Ocean	37	0.7	0.8	5.1[1]	2.1	VE	7-8
						AE	5-7

[†]All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Includes wave setup
[2]Wave runup elevation

TABLE 10 - TRANSECT DATA† - continued

FLOODING SOURCE	TRANSECT	STILLWATER ELEVATION (feet Local Tidal Datum) 10-PERCENT	2-PERCENT	1-PERCENT	0.2-PERCENT	ZONE	BASE FLOOD ELEVATION (feet Local Tidal Datum)
		Kauai County - continued					
Pacific Ocean	38	0.7	0.8	5.2[1]	2.3	VE	7-8
						AE	6-7
		0.7	0.8	1.1	2.3	AE	5[2]
Pacific Ocean	39	0.7	0.8	5.2[1]	2.3	VE	7-8
						AE	5-7
Pacific Ocean	40	0.7	0.8	5.1[1]	2.1	VE	7-8
						AE	5-7
Pacific Ocean	41	0.7	0.8	5.2[1]	2.2	VE	7-8
						AE	5-7
Pacific Ocean	42	0.7	0.8	5.6[1]	2.0	VE	8-9
						AE	8
		0.7	0.8	1.0	2.0	AE	7[2]
Pacific Ocean	43	0.7	0.8	5.4[1]	2.1	VE	7-8
						AE	5-7
Pacific Ocean	44	0.7	0.8	5.6[1]	2.0	VE	8-9
						AE	6-8
Pacific Ocean	45	0.7	0.8	5.6[1]	1.7	VE	8-9
						AE	6-8

†All elevations reflect the hurricane surge hazard only. Tsunami hazards may dominate in certain areas.
[1]Includes wave setup
[2]Wave runup elevation

All elevations are referenced to Local Tidal Datum. Benchmarks provided by the NGS were used in this study are shown on the FIRM. The elevations associated with each NGS benchmark were obtained during FIS production to establish vertical control for determination of flood elevations and floodplain boundaries shown on the FIRM. To obtain up-to-date elevation information on National Geodetic Survey (NGS) benchmarks shown on this map, please contact the Information Services Branch of the NGS at (301) 713-3242, or visit their website at www.ngs.noaa.gov. Map users should seek verification of non-NGS ERM monument elevations when using these elevations for construction or floodplain management purposes.

Qualifying bench marks within a given jurisdiction that are cataloged by the National Geodetic Survey (NGS) and entered into the National Spatial Reference System (NSRS) as First or Second Order Vertical and have a vertical stability classification of A, B, or C are shown and labeled on the FIRM with their 6-character NSRS Permanent Identifier.

Bench marks cataloged by the NGS and entered into the NSRS vary widely in vertical stability classification. NSRS vertical stability classifications are as follows:

- Stability A: Monuments of the most reliable nature, expected to hold position/elevation well (e.g., mounted in bedrock)
- Stability B: Monuments that generally hold their position/elevation well (e.g., concrete bridge abutment)
- Stability C: Monuments that may be affected by surface ground movements (e.g., concrete monument below frost line)
- Stability D: Mark of questionable or unknown vertical stability (e.g., concrete monument above frost line, or steel witness post)

In addition to NSRS benchmarks, the FIRM may also show vertical control monuments established by a local jurisdiction; these monuments will be shown on the FIRM with the appropriate designations. Local monuments will only be placed on the FIRM if the community has requested that they be included, and if the monuments meet the aforementioned NSRS inclusion criteria.

It is important to note that temporary vertical monuments are often established during the preparation of a flood hazard analysis for the purpose of establishing local vertical control. Although these monuments are not shown on the FIRM, they may be found in the Technical Support Data Notebook associated with this FIS and FIRM. Interested individuals may contact FEMA to access this data.

Behind-Levee Analyses

Some flood hazard information presented in prior FIRMs and in prior FIS reports for Kauai County and its incorporated communities was based on flood protection provided by levees. Based on the information available and the mapping standards of the National Flood Insurance Program (NFIP) at the time that the prior FISs and FIRMs were prepared, FEMA accredited the levees as providing protection from the flood that has a 1-percent annual chance of being equaled or exceeded in any given year. For FEMA to continue to accredit the identified levees with providing protection from the base flood, the levees must meet the criteria of the Code of Federal Regulations, Title 44, Chapter I, Section 65.10 (44 CFR 65.10), titled "Mapping of Areas Protected by Levee Systems."

On August 22, 2005, FEMA issued "Procedure Memorandum No. 34 – Interim Guidance for Studies Including Levees." The purpose of the memorandum was to help clarify the responsibility of community officials or other parties seeking recognition of a levee by providing information identified during a study/mapping project. Often, documentation regarding levee design, accreditation, and the impacts on flood hazard mapping is outdated or missing altogether. To remedy this, Procedure Memorandum No. 34 provides interim guidance on procedures to minimize delays in near-term studies/mapping projects, to help our mapping partners properly assess how to handle levee mapping issues.

While documentation related to 44 CFR 65.10 is being compiled, the release of a more up-to-date FIRM for other parts of a community or county may be delayed. To minimize the impact of the levee recognition and certification process, FEMA issued “Procedure Memorandum No. 43 – Guidelines for Identifying Provisionally Accredited Levees” on March 16, 2007. These guidelines allow issuance of the FIS and FIRM while levee owners or communities compile full documentation required to show compliance with 44 CFR 65.10. The guidelines also explain that a FIRM can be issued while providing the communities and levee owners with a specified timeframe to correct any maintenance deficiencies associated with a levee and to show compliance with 44 CFR 65.10.

FEMA contacted the communities within Kauai County to obtain data required under 44 CFR 65.10 to continue to show the levees as providing protection from the flood that has a 1-percent annual chance of being equaled or exceeded in any given year.

FEMA understood that it may take time to acquire and/or assemble the documentation necessary to fully comply with 44 CFR 65.10. Therefore, FEMA put forth a process to provide the communities with additional time to submit all the necessary documentation. For a community to avail itself of the additional time, it had to sign an agreement with FEMA. Levees for which such agreements were signed are shown on the final effective FIRM as providing protection from the flood that has a 1-percent annual chance of being equaled or exceeded in any given year and labeled as a Provisionally Accredited Levee (PAL). Communities have two years from the date of FEMA’s initial coordination to submit to FEMA final accreditation data for all PALs. Following receipt of final accreditation data, FEMA will revise the FIS and FIRM as warranted.

FEMA coordinated with the local communities and other organizations to compile a list of levees based on information from the FIRM and community provided information.

Approximate analyses of “behind levee” flooding were conducted for all the levees to indicate the extent of the “behind levee” floodplains. The methodology used in these analyses is discussed below.

Levee with inventory ID #3 is located on Waikaea Canal. Based on detailed topographic information obtained using LiDAR part of the shaded zone X area to the north of the levee was recommended as the behind levee floodplain.

Levee with inventory ID # 4 is located on Moikeha Canal. Based on detailed topographic information obtained using LiDAR part of the shaded zone X area to the north of the levee was recommended as the behind levee floodplain.

A portion of the Kuhio Highway embankment, with inventory ID # 5, is located on the Kapaa Stream. Runoff from up-gradient areas drains towards Kuhio Highway and is constricted at the highway due to the embankment. Based on detailed topographic information obtained using LiDAR the behind levee floodplain was delineated over the highway.

A portion of Kuhio Highway embankment, with inventory ID # 7, is located on the Wailua River. Based on detailed topographic information obtained using LiDAR the behind levee floodplain was delineated east of the highway.

Levees with inventory ID # 9, 10, and 12 are located on the Waimea River. The behind levee floodplain was delineated using the base flood elevations from Waimea River and detailed topographic information obtained using LiDAR.

Levee with inventory ID #13 is located on the Hanapepe River. The behind levee floodplain was delineated using the base flood elevations from Hanapepe River and detailed topographic information obtained using LiDAR.

A portion of Kaumaulii Highway embankment, with inventory ID # 14, is located on Lawai Stream. Runoff from up-gradient areas drains toward Kaumaulili Highway and is constricted at the highway due to the embankment. Based on topographic information from the USGS (10m DEMs) the behind levee floodplain was delineated over the highway.

A portion of the Kuhio Highway embankment, with inventory ID # 15, is located on Hananmaula Stream. Runoff from up-gradient areas drains towards Kuhio Highway and is constricted at the highway due to the embankment. Based on detailed topographic information obtained using LiDAR the behind levee floodplain was delineated over the highway.

3.3 Vertical Datum

All FISs and FIRMs are referenced to a specific vertical datum. The vertical datum provides a starting point against which flood, ground, and structure elevations can be referenced and compared.

All flood elevations shown in this FIS report and on the FIRM are referenced to Local Tidal Datum. Structure and ground elevations in the community must, therefore, be referenced to Local Tidal Datum.

For more information on datums, see Converting the National Flood Insurance Program to the North American Vertical Datum of 1988, FEMA Publication FIA-20/June 1992, or contact the Vertical Network Branch, National Geodetic Survey, Coast and Geodetic Survey, National Oceanic and Atmospheric Administration, Silver Spring, Maryland 20910 (Internet address http://www.ngs.noaa.gov).

4.0 FLOODPLAIN MANAGEMENT APPLICATIONS

The NFIP encourages State and local governments to adopt sound floodplain management programs. To assist in this endeavor, each FIS provides 1-percent-annual-chance floodplain data, which may include a combination of the following: 10-, 2-, 1-, and 0.2-percent-annual-chance flood elevations; delineations of the 1- and 0.2-percent-annual-chance floodplains; and 1-percent-annual-chance floodway. This information is presented on the FIRM and in many components of the FIS, including Flood Profiles, Floodway Data tables, and Summary of Stillwater Elevation tables. Users should reference the data presented in the FIS as well as additional information that may be available at the local community map repository before making flood elevation and/or floodplain boundary determinations.

4.1 Floodplain Boundaries

To provide a national standard without regional discrimination, the 1-percent-annual-chance flood has been adopted by FEMA as the base flood for floodplain management purposes. The 0.2-percent-annual-chance flood is employed to indicate additional areas of flood risk in the county. For the streams studied in detail, the 1- and 0.2-percent-annual-chance floodplain boundaries have been delineated using the flood elevations determined at each cross section. Between cross sections, the boundaries were interpolated using topographic maps at a scale of 1:2,400, 1:4,800, and 1:24,000, with contour intervals of 1, 5, and 40 feet (Kauai Co. 1975; USACE 1973, 1974, 1975, 1977, 1984; USDA 1977; USGS 1963, 1965).

The 1- and 0.2-percent-annual-chance floodplain boundaries are shown on the FIRM (Exhibit 2). On this map, the 1-percent-annual-chance floodplain boundary corresponds to the boundary of the areas of special flood hazards (Zones A, AE, AO, AH, V, and VE), and the 0.2-percent-annual-chance floodplain boundary corresponds to the boundary of areas of moderate flood hazards. In cases where the 1- and 0.2-percent-annual-chance floodplain boundaries are close together, only the 1-percent-annual-chance floodplain boundary has been shown. Small areas within the floodplain boundaries may lie above the flood elevations but cannot be shown due to limitations of the map scale and/or lack of detailed topographic data.

On the Waimea River, the 1-percent annual chance floodplain boundary on the west bank is contained by the flood-control levee. The levee does not contain the 0.2-percent annual chance flood, and flooding of the areas adjacent to the river will occur during the 0.2-percent annual chance flood. The 1-percent annual chance floodplain boundaries in the Kekaha Drainageway area were delineated using topographic maps at a scale of 1:4,800, with contour intervals of 1 foot and 5 feet (USDA, 1977; and Kauai County, 1983, respectively).

The coastal high hazard area, i.e., that portion of the coast that is inundated by the 1-percent annual chance tsunami wave and that exhibits wave action, was determined using tsunami wave elevations and runup elevations. The limit of runup is computed using runup elevations and known aerial topographic characteristics, and based on the maximum or limiting inundation line having a tsunami wave depth of 0 feet.

For the areas studied by approximate methods, only the 1-percent annual chance flood plain boundary is shown on the Flood Insurance Rate Map (Exhibit 2).

The 1-percent annual chance floodplain boundaries for areas of approximate study were determined by various methods and are grouped under the three categories:

1. Approximate 1-percent annual chance floodplain boundaries determined by this study using the hydrologic and hydraulic methods described earlier for areas studied by approximate methods. These include Limahuli Stream, Manoa Stream, Stream No. 1, and Waihohonu Streams.

2. Approximate 1-percent annual chance floodplain boundaries extracted from prior studies. These include the Wainiha River, Kealia Stream, Opaekaa Stream (lower portion), Hanamaulu Stream, Lawai Stream (upper portion), and the Waimea River.

3. Approximate 1-percent annual chance floodplain boundaries extracted from a Flood-Prone Area Map (USGS, 1974). No hydrologic or hydraulic analyses were performed. These include the Lumahai River, the Kalihiwai River, Kilauea Stream, Moloaa Stream, and Papaa Stream.

4. Approximate analysis of "behind levee" flooding were conducted for all the levees in the County of Kauai. The approximate 1-percent annual chance floodplain boundaries behind levees were determined by this analysis. The behind levee floodplain was assign either shaded Zone X if the levee is Provisionally Accredited levee (PAL), or Zone A if the levee is not a PAL. The behind levee floodplain were determined based on either riverside BFEs, or engineering judgment and topographic information obtained by LiDAR method.

4.2 Floodways

Encroachment on floodplains, such as structures and fill, reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of floodplain management involves balancing the economic gain from floodplain development against the resulting increase in flood hazard. For purposes of the NFIP, a floodway is used as a tool to assist local communities in this aspect of floodplain management. Under this concept, the area of the 1-percent annual chance floodplain is divided into a floodway and a floodway fringe. The floodway is the channel of a stream, plus any adjacent floodplain areas, that must be kept free of encroachment so that the 1-percent annual chance flood can be carried without substantial increases in flood heights. Minimum federal standards limit such increases to 1.0 foot, provided that hazardous velocities are not produced. The floodways in this FIS are presented to local agencies as minimum standards that can be adopted directly or that can be used as a basis for additional floodway studies.

The floodways presented in this study were computed for certain stream segments on the basis of equal conveyance reduction from each side of the flood plain. Floodway widths were computed at cross sections. Between cross sections, the floodway boundaries were interpolated. The results of the floodway computations are tabulated for selected cross sections (Table 11). The computed floodways are shown on the Flood Insurance Rate Map (Exhibit 2). In cases where the floodway and 1-percent annual chance floodplain boundaries are either close together or collinear, only the floodway boundary is shown.

For certain sections of the streams studied in detail, encroachment was not recommended in areas where hazardous velocities were encountered or where other considerations make encroachment undesirable. Therefore, portions of the floodway boundaries for following streams are shown coincident with the 1-percent annual chance floodplain boundaries:

Anahola Stream	Waikaea Canal
Hanalei River	Waikomo Stream
Lawai Stream	Waimea River
Moikeha Canal	Wainiha River
Nawiliwili Stream	Waipa Stream
Omao Stream	Waioli Stream
Opaekaa Tributary	

Floodways were not deemed appropriate in the Kekaha Drainageway area because of shallow flooding conditions. For streams discharging into the ocean, the floodway boundaries were terminated at the coastal high-hazard boundary.

The area between the floodway and 1-percent annual chance floodplain boundaries is termed the floodway fringe. The floodway fringe encompasses the portion of the floodplain that could be completely obstructed without increasing the water-surface elevation of the 1-percent-annual-chance flood by more than 1.0 foot at any point. Typical relationships between the floodway and the floodway fringe and their significance to floodplain development are shown in Figure 5.

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Anahola Stream								
A	1,060 [1]	555	3,879	7.5	8.6	8.6	8.7	0.1
B	1,630 [1]	768	4,793	6.1	9.7	9.7	9.8	0.1
C	1,900 [1]	980	7,531	3.4	10.9	10.9	11.0	0.1
D	2,165 [1]	1,050	9,703	3.0	11.3	11.3	11.4	0.1
E	2,680 [1]	1,160	9,402	3.4	11.4	11.4	11.6	0.2
F	3,300 [1]	789	4,059	7.1	11.5	11.5	12.0	0.5
Hanalei River								
A	5,160 [2]	3,434	30,081	1.9	12.0	12.0	12.9	0.9
B	8,000 [2]	4,432	33,674	1.7	13.1	13.1	13.9	0.8
C	9,700 [2]	2,330	16,246	3.6	14.3	14.3	14.9	0.6
D	10,400 [2]	2,180	20,943	2.8	15.9	15.9	16.1	0.2
E	12,000 [2]	1,930	14,214	4.1	16.1	16.1	16.4	0.3
F	14,500 [2]	1,656	16,146	3.6	19.7	19.7	20.4	0.7
G	17,600 [2]	1,236	17,761	3.3	24.3	24.3	24.8	0.5
H	19,400 [2]	1,335	12,254	4.7	26.6	26.6	27.2	0.6
I	20,600 [2]	1,517	13,110	4.4	28.7	28.7	29.3	0.6
J	23,400 [2]	811	5,685	10.2	36.1	36.1	36.6	0.5

[1]Stream distance in feet above confluence with Anahola Bay
[2]Stream distance in feet above confluence with Hanalei Bay

TABLE 11

FEDERAL EMERGENCY MANAGEMENT AGENCY

KAUAI COUNTY, HI

FLOODWAY DATA

ANAHOLA STREAM – HANALEI RIVER

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Hanamaulu Stream								
A	1,110 [1]	226	1,828	14.9	11.1[2]	10.4	10.7	0.3
B	1,930 [1]	574	6,560	4.2	17.5	17.5	18.3	0.8
C	3,140 [1]	888	10,362	2.6	18.0	18.0	18.7	0.7
D	4,380 [1]	540	5,430	5.0	18.2	18.2	18.9	0.7
E	5,750 [1]	331	2,795	9.8	21.8	21.8	22.3	0.5
F	7,275 [1]	293	4,736	5.8	34.3	34.3	34.9	0.6
G	8,795 [1]	107	1,659	16.5	49.6	49.6	49.6	0.0
H	10,435 [1]	202	2,185	12.5	74.3	74.3	74.3	0.0
I	11,945 [1]	250	2,615	10.4	88.5	88.5	89.2	0.7
J	12,317 [1]	130	2,731	5.9	110.6	110.6	110.6	0.0
K	13,277 [1]	58	796	20.2	116.1	116.1	116.4	0.3
Hanamaulu Stream Tributary								
A	125 [3]	162	2,814	4.0	104.4	104.4	104.4	0.0
B	825 [3]	136	2,607	4.3	105.5	105.5	106.0	0.5

[1]Stream distance in feet above confluence with Hanamaulu Bay
[2]Elevation influenced by Hanamaulu Bay
[3]Stream distance in feet above confluence with Hanamaulu Stream

TABLE 11

FEDERAL EMERGENCY MANAGEMENT AGENCY

KAUAI COUNTY, HI

FLOODWAY DATA

HANAMAULU STREAM – HANAMAULU STREAM TRIBUTARY

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Hanapepe River								
A	2,800 [1]	205	3,373	11.3	12.4	12.4	13.1	0.7
B	3,600 [1]	242	4,167	9.1	14.0	14.0	14.5	0.5
C	4,450 [1]	197	3,057	12.4	14.0	14.0	14.5	0.5
D	5,650 [1]	806	6,009	6.3	15.5	15.5	15.6	0.1
E	8,910 [1]	490	2,708	14.0	23.3	23.3	23.5	0.2
F	11,400 [1]	390	2,838	13.4	37.8	37.8	37.9	0.1
Huleia Stream								
A	260 [2]	650	6,225	6.5	6.7	6.7	6.7	0.0
B	660 [2]	530	5,058	7.9	6.7	6.7	6.7	0.0
C	1,460 [2]	400	4,221	9.5	7.5	7.5	7.5	0.0
D	2,260 [2]	380	4,699	8.5	8.3	8.3	8.6	0.3
E	3,060 [2]	460	6,075	6.6	9.5	9.5	9.8	0.3
F	3,860 [2]	1,090	12,595	3.2	10.3	10.3	10.7	0.4
G	4,660 [2]	1,080	12,472	3.2	10.4	10.4	10.8	0.4
H	5,060 [2]	465	5,953	6.7	10.4	10.4	10.8	0.4
I	5,860 [2]	317	4,414	8.1	12.8	12.8	12.8	0.0
J	6,460 [2]	235	3,696	9.7	12.8	12.8	12.8	0.0
K	7,060 [2]	411	4,511	8.0	13.7	13.7	13.7	0.0
L	7,860 [2]	466	5,320	6.8	14.4	14.4	14.4	0.0
M	8,260 [2]	454	5,053	7.1	14.6	14.6	14.6	0.0
N	9,460 [2]	535	7,301	4.9	14.9	14.9	15.5	0.6
O	10,260 [2]	583	7,853	4.6	15.0	15.0	15.8	0.8
P	11,060 [2]	540	6,422	5.6	15.1	15.1	15.9	0.8
Q	11,860 [2]	357	3,867	9.3	15.1	15.1	16.1	1.0
R	12,660 [2]	281	2,437	13.0	19.0	19.0	19.0	0.0
S	13,060 [2]	282	3,205	9.9	22.9	22.9	23.8	0.9

[1] Stream distance in feet above confluence with Hanapepe Bay
[2] Stream distance in feet above confluence with Nawiliwili Bay

TABLE 11

FEDERAL EMERGENCY MANAGEMENT AGENCY

KAUAI COUNTY, HI

FLOODWAY DATA

HANAPEPE RIVER – HULEIA STREAM

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Kalama Stream								
A	315	86	978	8.4	284.4	284.4	285.4	1.0
B	920	159	1,764	4.7	286.1	286.1	286.8	0.7
C	1,660	170	830	9.0	286.2	286.2	287.1	0.9
D	2,730	255	2,120	3.5	296.5	296.5	297.3	0.8
E	3,890	296	1,383	4.4	298.1	298.1	298.8	0.7
F	4,870	55	472	12.9	298.1	298.1	298.8	0.7
G	6,350	80	711	8.6	303.0	303.0	303.6	0.6
H	6,870	140	718	8.5	304.8	304.8	305.3	0.5
I	8,520	114	698	8.7	312.0	312.0	312.1	0.1
J	9,210	264	1,469	4.2	313.4	313.4	314.0	0.6
K	9,780	211	1,070	5.7	313.9	313.9	314.5	0.6
L	10,450	198	1,076	5.2	320.4	320.4	320.6	0.2
M	11,800	200	814	6.9	326.2	326.2	326.8	0.6
N	12,350	163	911	6.6	327.8	327.8	328.8	1.0
O	13,050	63	426	14.1	331.5	331.5	331.6	0.1
P	13,600	72	579	10.4	336.8	336.8	337.0	0.2
Q	14,650	379	1,659	2.8	350.4	350.4	350.9	0.5
R	15,720	46	318	14.4	362.9	362.9	363.2	0.3
S	16,320	62	593	7.7	379.5	379.5	380.5	1.0
T	17,170	108	612	7.5	400.2	400.2	400.7	0.5

[1]Stream distance in feet above confluence with Opaekaa Stream

TABLE 11

FEDERAL EMERGENCY MANAGEMENT AGENCY

KAUAI COUNTY, HI

FLOODWAY DATA

KALAMA STREAM

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE[1]	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Kapaa Stream								
A	1,875	1,572	22,943	1.6	21.3	21.3	21.5	0.2
B	2,775	1,947	28,998	1.2	21.3	21.3	21.6	0.3
C	3,600	1,855	25,649	1.4	21.4	21.4	21.6	0.2
D	4,700	1,061	14,702	2.4	21.4	21.4	21.6	0.2
E	6,000	679	8,909	3.9	21.5	21.5	21.8	0.3
F	6,430	359	5,832	5.9	21.6	21.6	21.8	0.2
G	7,400	484	6,485	5.3	22.0	22.0	22.4	0.4
H	7,935	497	5,380	6.4	22.2	22.2	22.6	0.4
I	8,600	337	5,475	6.3	23.2	23.2	23.8	0.6
J	9,350	430	7,393	4.6	24.3	24.3	24.8	0.5
K	10,000	765	7,700	4.4	24.6	24.6	25.2	0.6
L	10,300	768	6,592	5.1	24.7	24.7	25.2	0.5
M	11,100	197	3,001	11.3	24.8	24.8	25.2	0.4
N	12,700	216	2,531	13.4	27.6	27.6	28.3	0.7

[1]Stream distance in feet above confluence with Kauai Channel

TABLE 11

FEDERAL EMERGENCY MANAGEMENT AGENCY

KAUAI COUNTY, HI

FLOODWAY DATA

KAPAA STREAM

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Lawai Stream								
A	100 [1]	77	500	13.3	383.5	383.5	383.5	0.0
B	500 [1]	80	487	13.7	387.2	387.2	387.6	0.4
C	900 [1]	95	571	11.7	393.8	393.8	393.8	0.0
D	1,200 [1]	94	525	12.7	397.6	397.6	398.5	0.9
E	1,600 [1]	72	504	13.2	410.6	410.6	410.6	0.0
F	1,900 [1]	104	614	10.8	414.2	414.2	415.1	0.9
G	3,100 [1]	58	460	13.9	444.2	444.2	444.3	0.1
H	3,500 [1]	106	544	11.8	452.2	452.2	452.4	0.2
I	3,800 [1]	102	564	11.4	459.0	459.0	459.2	0.2
J	4,200 [1]	146	500	12.3	467.1	467.1	467.3	0.2
K	4,500 [1]	86	570	10.8	475.1	475.1	475.1	0.0
L	4,900 [1]	100	422	14.6	482.6	482.6	482.6	0.0
M	5,200 [1]	79	484	12.8	489.1	489.1	489.4	0.3
N	6,100 [1]	71	786	7.8	512.7	512.7	512.8	0.1
O	6,600 [1]	118	841	7.3	517.7	517.7	518.7	1.0
P	6,900 [1]	83	503	12.3	525.9	525.9	526.3	0.4
Q	7,200 [1]	60	462	13.4	530.8	530.8	531.4	0.6
R	7,700 [1]	91	494	12.5	542.8	542.8	542.8	0.0
S	8,100 [1]	78	467	13.2	548.2	548.2	548.4	0.2
Moikeha Canal								
A	1,255 [2]	*	509	3.0	5.1	5.1	5.8	0.7
B	1,800 [2]	*	314	4.8	5.1	5.1	5.8	0.7
C	1,914 [2]	*	340	4.4	5.8	5.8	6.4	0.6
D	2,915 [2]	*	593	2.4	6.1	6.1	6.9	0.8
E	3,500 [2]	*	432	2.9	6.2	6.2	7.0	0.8
F	4,120 [2]	*	462	2.3	6.5	6.5	7.2	0.7
G	4,300 [2]	*	235	3.9	6.5	6.5	7.2	0.7
H	5,310 [2]	151	162	4.6	14.7	14.7	14.8	0.1

[1]Stream distance in feet above Limit of Detailed Study**

**Limit of Detailed Study is approximately 2,540 feet downstream of Lauoho Road

[2]Stream distance in feet above confluence with Kauai Channel

*Floodway coincident with channel banks

TABLE 11

FEDERAL EMERGENCY MANAGEMENT AGENCY

KAUAI COUNTY, HI

FLOODWAY DATA

LAWAI STREAM – MOIKEHA CANAL

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Nawiliwili Stream								
A	625 [1]	397	3,777	2.8	16.8	16.8	17.7	0.9
B	880 [1]	256	2,893	3.6	16.9	16.9	17.8	0.9
C	1,720 [1]	615	6,347	1.6	17.2	17.2	18.2	1.0
D	2,720 [1]	354	2,617	4.0	17.3	17.3	18.2	0.9
E	3,170 [1]	203	1,134	9.2	17.5	17.5	18.2	0.7
F	7,700 [1]	101	1,096	9.2	94.1	94.1	94.7	0.6
G	8,340 [1]	87	753	13.0	97.5	97.5	97.5	0.0
H	9,020 [1]	111	1,180	8.3	102.9	102.9	103.7	0.8
I	10,200 [1]	68	666	14.6	112.7	112.7	113.4	0.7
J	11,520 [1]	118	1,221	8.0	121.5	121.5	122.2	0.7
K	12,600 [1]	174	959	10.2	133.2	133.2	133.3	0.1
L	13,390 [1]	158	1,774	5.5	136.9	136.9	137.9	1.0
M	14,470 [1]	112	834	11.7	147.6	147.6	147.6	0.0
N	16,200 [1]	162	1,713	5.5	158.6	158.6	159.4	0.8
O	17,600 [1]	80	670	14.1	162.4	162.4	162.5	0.1
Omao Stream								
A	270 [2]	237	1,301	3.4	213.9	213.9	214.7	0.8
B	1,300 [2]	160	738	6.0	214.3	214.3	215.3	1.0
C	2,400 [2]	311	1,105	4.0	221.7	221.7	222.7	1.0
D	3,600 [2]	170	859	5.1	224.4	224.4	225.3	0.9
E	4,400 [2]	341	1,589	2.8	226.6	226.6	227.4	0.8
F	5,030 [2]	85	682	6.5	227.2	227.2	228.0	0.8

[1]Stream distance in feet above confluence with Nawiliwili Bay
[2]Stream distance in feet above confluence with Waikomo Stream

TABLE 11

FEDERAL EMERGENCY MANAGEMENT AGENCY

KAUAI COUNTY, HI

FLOODWAY DATA

NAWILIWILI STREAM – OMAO STREAM

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Opaekaa Stream								
A	-2,970 [1]	90	1,232	12.6	275.7	275.7	276.7	1.0
B	-2,090 [1]	104	1,568	9.9	281.4	281.4	281.7	0.3
C	-1,030 [1]	102	1,384	11.2	283.5	283.5	284.2	0.7
D	-370 [1]	169	2,148	4.4	287.3	287.3	288.3	1.0
E	190 [1]	82	1,199	7.8	289.5	289.5	289.5	0.0
F	970 [1]	157	1,173	8.0	289.5	289.5	289.9	0.4
G	1,810 [1]	130	1,509	6.2	294.0	294.0	294.3	0.3
H	2,550 [1]	133	1,396	6.7	296.0	296.0	296.1	0.1
I	3,370 [1]	148	1,687	5.6	297.9	297.9	298.3	0.4
J	3,680 [1]	145	1,670	2.6	298.0	298.0	299.0	1.0
K	4,080 [1]	251	2,425	1.6	298.2	298.2	299.2	1.0
L	4,480 [1]	110	1,262	3.0	298.2	298.2	299.2	1.0
M	4,880 [1]	173	1,799	2.1	298.7	298.7	299.7	1.0
N	5,280 [1]	75	698	5.4	298.9	298.9	299.9	1.0
O	5,980 [1]	210	1,559	2.3	300.8	300.8	301.5	0.7
P	6,480 [1]	70	506	7.1	302.3	302.3	302.6	0.3
Q	7,080 [1]	117	807	4.4	305.0	305.0	305.7	0.7
R	7,480 [1]	80	533	6.7	307.6	307.6	307.6	0.0
S	7,780 [1]	120	1,042	3.2	308.8	308.8	309.8	1.0
T	8,280 [1]	90	627	5.4	309.0	309.0	310.0	1.0
U	8,680 [1]	65	536	6.3	310.4	310.4	310.9	0.5
Opaekaa Tributary								
A	400 [2]	85	265	3.4	289.1	289.1	289.2	0.1
B	740 [2]	195	1,661	0.5	300.2	300.2	301.2	1.0
C	1,000 [2]	53	325	2.8	300.2	300.2	301.2	1.0
D	1,300 [2]	70	120	7.5	303.5	303.5	303.5	0.0
E	1,640 [2]	76	629	1.3	311.5	311.5	312.4	0.9
F	1,940 [2]	30	109	7.7	311.6	311.6	312.5	0.9

[1]Stream distance in feet from Kamalu Road
[2]Stream distance in feet above confluence with Opaekaa Stream

TABLE 11

FEDERAL EMERGENCY MANAGEMENT AGENCY

KAUAI COUNTY, HI

FLOODWAY DATA

OPAEKAA STREAM – OPAEKAA TRIBUTARY

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Papakolea Stream								
A	800 [1]	648	1,814	3.9	14.6[2]	8.1	8.8	0.7
B	1,400 [1]	331	1,554	4.5	14.6[2]	10.9	11.9	1.0
C	1,700 [1]	191	672	10.5	14.6[2]	11.9	12.6	0.7
D	2,000 [1]	101	619	11.4	15.1	15.1	15.9	0.8
E	2,300 [1]	74	491	14.4	17.7	17.7	18.0	0.3
Puali Stream								
A	615 [3]	332	1,666	4.0	8.3	8.3	9.2	0.9
B	730 [3]	566	2,742	2.4	9.2	9.2	10.2	1.0
C	1,040 [3]	314	1,805	3.7	9.4	9.4	10.3	0.9
D	1,930 [3]	162	845	7.8	11.8	11.8	12.0	0.2
Waikaea Canal								
A	950 [4]	154	881	6.1	7.7	7.7	7.8	0.1
B	1,235 [4]	87	658	8.2	7.7	7.7	7.8	0.1
C	1,380 [4]	236	1,167	4.6	8.9	8.9	9.0	0.1
D	1,800 [4]	514	3,288	1.6	9.2	9.2	9.4	0.2
E	2,300 [4]	853	4,194	1.3	9.2	9.2	9.5	0.3
F	2,765 [4]	730	4,342	1.2	9.3	9.3	9.5	0.2
G	4,080 [4]	988	4,881	1.0	9.3	9.3	9.6	0.3
H	5,225 [4]	190	837	5.7	9.3	9.3	9.6	0.3

[1]Stream distance in feet above confluence with Huleia Stream
[2]Backwater elevations from Huleia Stream
[3]Stream distance in feet above confluence with Nawiliwili Bay
[4]Stream distance in feet above confluence with Pacific Ocean

TABLE 11

FEDERAL EMERGENCY MANAGEMENT AGENCY

KAUAI COUNTY, HI

FLOODWAY DATA

PAPAKOLEA STREAM – PUALI STREAM – WAIKAEA CANAL

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Waikomo Stream								
A	1,160 [1]	167	1,268	7.1	38.8	38.8	39.7	0.9
B	3,200 [1]	110	789	10.7	73.6	73.6	74.6	1.0
C	5,570 [1]	116	621	12.8	114.5	114.5	114.6	0.1
D	6,980 [1]	239	703	11.3	146.4	146.4	147.4	1.0
E	7,330 [1]	100	528	15.0	151.6	151.6	151.7	0.1
F	8,400 [1]	162	582	12.8	174.5	174.5	175.1	0.6
G	10,760 [1]	308	1,778	4.2	204.4	204.4	205.4	1.0
H	12,600 [1]	351	2,043	3.4	213.6	213.6	214.1	0.5
I	13,890 [1]	399	2,682	0.9	216.7	216.7	217.4	0.7
J	15,875 [1]	121	527	4.7	217.2	217.2	218.0	0.8
K	16,835 [1]	168	839	2.2	220.7	220.7	220.8	0.1
L	17,675 [1]	443	2,388	0.8	222.5	222.5	223.5	1.0
Waikomo Stream Tributary								
A	165 [2]	164	968	0.7	220.6	220.6	220.6	0.0
B	1,135 [2]	40	323	2.1	220.6	220.6	220.6	0.0

[1]Stream distance in feet above confluence with Pacific Ocean
[2]Stream distance in feet above confluence with Waikomo Stream

TABLE 11

FEDERAL EMERGENCY MANAGEMENT AGENCY

KAUAI COUNTY, HI

FLOODWAY DATA

WAIKOMO STREAM – WAIKOMO STREAM TRIBUTARY

FLOODING SOURCE		FLOODWAY			BASE FLOOD WATER-SURFACE ELEVATION (FEET LOCAL TIDAL DATUM)			
CROSS SECTION	DISTANCE	WIDTH (FEET)	SECTION AREA (SQUARE FEET)	MEAN VELOCITY (FEET PER SECOND)	REGULATORY	WITHOUT FLOODWAY	WITH FLOODWAY	INCREASE
Wailua River								
A	1,000 [1]	1,125	14,711	5.2	15.0	15.0	15.0	0.0
B	1,650 [1]	1,700	19,417	3.9	15.2	15.2	15.3	0.1
C	2,800 [1]	1,276	14,315	5.1	15.2	15.2	15.5	0.3
D	4,600 [1]	994	14,588	4.8	16.4	16.4	16.8	0.4
E	5,565 [1]	881	14,500	4.8	17.1	17.1	17.6	0.5
F	6,460 [1]	845	13,017	5.2	17.5	17.5	18.0	0.5
G	7,990 [1]	463	8,770	7.4	18.5	18.5	19.0	0.5
H	8,700 [1]	684	8,992	7.1	19.2	19.2	19.7	0.5
I	9,300 [1]	735	11,595	5.4	20.5	20.5	21.0	0.5
J	10,160 [1]	314	7,167	8.5	21.0	21.0	21.5	0.5
K	10,800 [1]	383	7,257	6.5	22.0	22.0	22.5	0.5
L	11,400 [1]	315	7,608	6.2	23.1	23.1	23.6	0.5
M	12,400 [1]	356	6,854	6.4	23.6	23.6	24.1	0.5
Wainiha River								
A	2,400 [2]	841	8,975	6.2	17.5	17.5	18.5	1.0
B	2,800 [2]	780	7,924	7.0	18.6	18.6	19.5	0.9
C	3,300 [2]	744	4,982	11.2	20.4	20.4	21.4	1.0
D	3,800 [2]	649	4,253	13.1	26.4	26.4	26.9	0.5
E	4,200 [2]	640	4,666	11.9	30.2	30.2	31.0	0.8
F	4,700 [2]	810	5,909	9.1	33.8	33.8	34.7	0.9
G	5,300 [2]	773	4,771	11.2	37.5	37.5	38.5	1.0
Waioli Stream								
A	2,600 [3]	775	5,551	2.9	12.7	12.7	13.6	.9
B	4,400 [3]	876	7,039	2.3	13.1	13.1	14.1	1.0
C	5,800 [3]	908	3,923	4.1	13.5	13.5	14.5	1.0

[1]Stream distance in feet above confluence with Wailua Bay
[2]Stream distance in feet above confluence with Wainiha Bay
[3]Stream distance in feet above confluence with Hanalei Bay

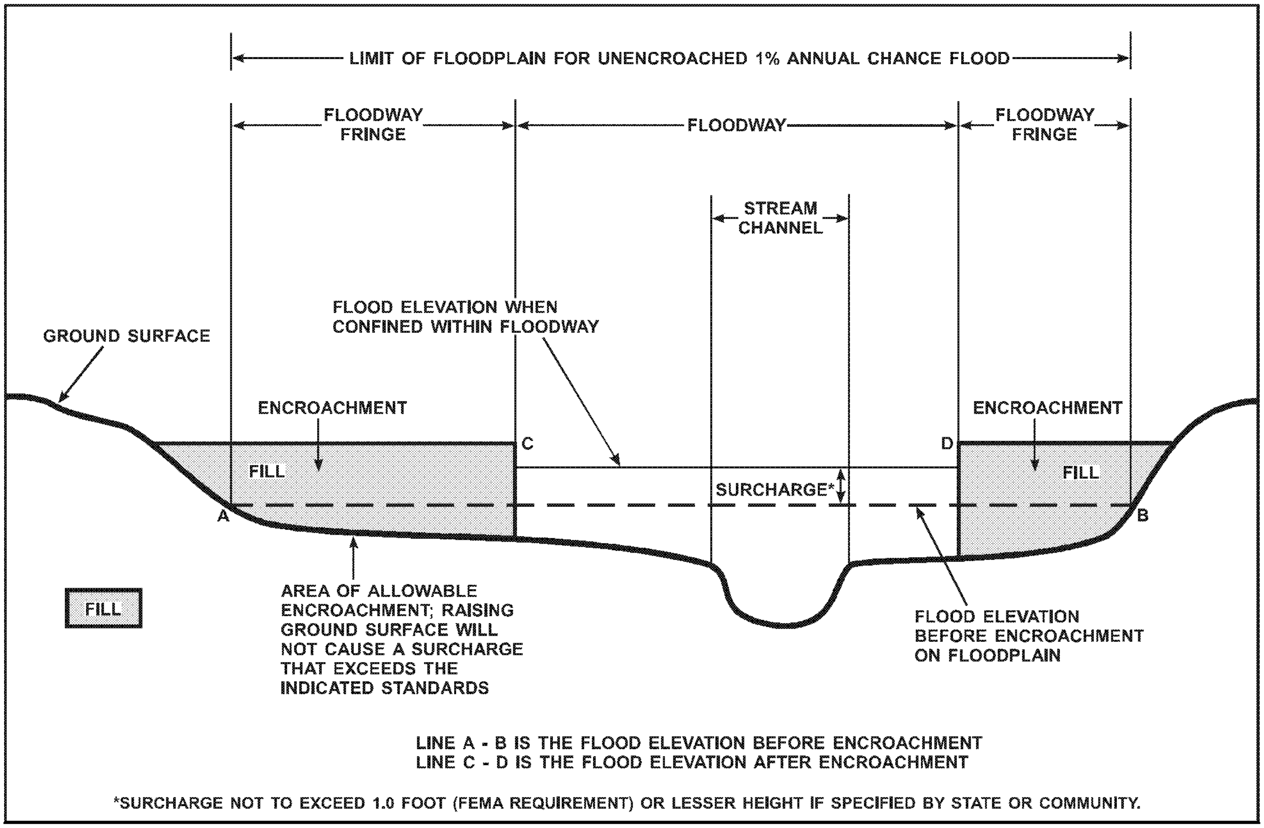
TABLE 11

FEDERAL EMERGENCY MANAGEMENT AGENCY

KAUAI COUNTY, HI

FLOODWAY DATA

WAILUA RIVER – WAINIHA RIVER – WAIOLI STREAM



FLOODWAY SCHEMATIC Figure 5

4.3 Tsunami and Hurricane Inundation Boundaries

Inundation limits from the 1-percent annual chance tsunami were computed from most of the shoreline of the Island of Kauai. The methodology employed in this computation is described in Section 4.1. The 1-percent annual chance tsunami inundation boundaries were delineated using methods outlined in Tsunami Inundation Prediction (Bretschneider and Wybro 1974), and either the topographic maps previously mentioned or USGS topographic maps (USGS 1963,1965).

The tsunami hazard was merged with the detailed hurricane coastal hazard study. This was accomplished by comparing the zone type and base flood elevation of coincident tsunami and hurricane storm surge hazards. The higher of the two elevations was retained and presented on the Flood Insurance Rate Map. In some cases, the dominant hazard transitioned from hurricane storm surge to tsunami (or vice-versa) moving inland: only a single transition was allowed. The VE Zone was mapped to the extent of the Primary Frontal Dune for both tsunami and hurricane hazards. In cases where elevations were similar, engineering judgment was applied to facilitate the most appropriate representation of the hazard.

Users of the FIRM should also be aware that coastal flood elevations are provided in the Summary of Stillwater Elevations table (Table 7) in this report. If the elevation on the FIRM is higher than the elevation shown in this table, a wave height, wave runup, and/or wave setup component likely exists, in which case, the higher elevation should be used for construction and/or floodplain management purposes.

As defined in the July 1989 *Guidelines and Specifications for Wave Elevation Determination and V Zone Mapping,* the coastal high hazard area (Zone VE) is the area where wave action and/or high velocity water can cause structural damage (*Guidelines and Specifications for Wave Elevation Determination and V-Zone Mapping*, FEMA, 1989). It is designated on the FIRM as the most landward of the following three points:

1) The point where the 3.0-foot or greater wave height could occur;
2) The point where the eroded ground profile is 3.0-foot or more below the maximum runup elevation; and
3) The primary frontal dune as defined in the NFIP regulations.

These three points are used to locate the inland limit of the coastal high hazard area to ensure that adequate insurance rates apply and appropriate construction standards are imposed, should local agencies permit building in this area.

The inundation limits for the 1-percent annual chance tsunami or hurricane are based on existing conditions. Any modification or alteration to existing conditions may have a significant effect on the inundation limits. On the one hand, any regrading or reduction of surface roughness in onshore areas, such as that caused by the removal of native vegetation could increase the extent of inundation. Similarly, dredge and fill operations offshore could increase the extent of inundation, as a result of the effects of coastal bathymetry on tsunami or hurricane wave setup. On the other hand, existing or planned coastal features such as natural reefs, seawalls, groins, jetties, or beach stabilization projects may have a mitigating effect on tsunami or hurricane inundation.

5.0 INSURANCE APPLICATIONS

For flood insurance rating purposes, flood insurance zone designations are assigned to a community based on the results of the engineering analyses. The zones are as follows:

Zone A

Zone A is the flood insurance rate zone that corresponds to the 1-percent-annual-chance floodplains that are determined in the FIS by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no base flood elevations or depths are shown within this zone.

Zone AE

Zone AE is the flood insurance rate zone that corresponds to the 1-percent-annual-chance floodplains that are determined in the FIS by detailed methods. In most instances, whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AH

Zone AH is the flood insurance rate zone that corresponds to the areas of 1-percent-annual-chance shallow flooding (usually areas of ponding) where average depths are between 1 and 3 feet. Whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone AO

Zone AO is the flood insurance rate zone that corresponds to the areas of 1-percent-annual-chance shallow flooding (usually sheet flow on sloping terrain) where average depths are between 1 and 3 feet. Average whole-foot depths derived from the detailed hydraulic analyses are shown within this zone.

Zone AR

Area of special flood hazard formerly protected from the 1-percent-annual-chance flood event by a flood control system that was subsequently decertified. Zone AR indicates that the former flood control system is being restored to provide protection from the 1-percent-annual-chance or greater flood event.

Zone A99

Zone A99 is the flood insurance rate zone that corresponds to areas of the 1-percent-annual-chance floodplain that will be protected by a Federal flood protection system where construction has reached specified statutory milestones. No base flood elevations or depths are shown within this zone.

Zone V

Zone V is the flood insurance rate zone that corresponds to the 1-percent-annual-chance coastal floodplains that have additional hazards associated with storm waves. Because approximate hydraulic analyses are performed for such areas, no base flood elevations are shown within this zone.

Zone VE

Zone VE is the flood insurance rate zone that corresponds to the 1-percent-annual-chance coastal floodplains that have additional hazards associated with storm waves. Whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

Zone X

Zone X is the flood insurance rate zone that corresponds to areas outside the 0.2-percent-annual-chance floodplain, areas within the 0.2-percent-annual-chance floodplain, and to areas of 1-percent-annual-chance flooding where average depths are less than 1 foot, areas of 1-percent-annual-chance flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 1-percent-annual-chance flood by levees. No base flood elevations or depths are shown within this zone.

Zone D

Zone D is the flood insurance rate zone that corresponds to unstudied areas where flood hazards are undetermined, but possible.

6.0 FLOOD INSURANCE RATE MAP

The FIRM is designed for flood insurance and floodplain management applications.

For flood insurance applications, the map designates flood insurance rate zones as described in Section 5.0 and, in the 1-percent annual chance floodplains that were studies by detailed methods, shows selected whole-foot base flood elevations or average depths. Insurance agents use the zones and base flood elevations in conjunction with information on structures and their contents to assign premium rates for flood insurance policies.

For floodplain management applications, the maps shows by tints, screens, and symbols, the 1- and 0.2-percent annual chance flood plains, the floodways, and the locations of selected cross sections used in the hydraulic analyses and floodway computations.

The current FIRM presents flooding information for the entire geographic area of Kauai County. Previously, separate Flood Hazard Boundary Maps and/or FIRMs were prepared for each identified flood-prone incorporated community within the county. This countywide FIRM also includes flood hazard information that was presented separately on Flood Boundary and Floodway Maps (FBFMs), where applicable. Historical data relating to the maps prepared for each community, up to and including this countywide FIS, are presented in Table 12, "Community Map History."

7.0 OTHER STUDIES

A number of reports have been prepared on flood-prone areas on the Island of Kauai. These reports were compared with the results of this study. All coastal flood elevations and boundaries of the selected tsunami recurrence intervals were analyzed in this study by a methodology not used in the earlier reports. This study employed the latest knowledge of tsunami elevation-frequency relationships and runup characteristics. Consequently, the tsunami flood elevations and boundaries differ from those given in the earlier reports, although in a few areas the results are similar.

Difference in riverine flood elevations and flood plain boundaries between this study and the earlier reports are caused primarily by dissimilar flood discharges. These discharge differences can be attributed to any one or more of the following reasons: different hydrologic methods employed, an increase of stream gage data, and considerations made for the attenuating effects of reservoir storage capacities. Other factors that can account for differences in flood elevations and boundaries are stream cross-section data, computer programs and topographic maps used, and the assumptions and estimations made in the hydraulic analyses of the flood plains.

For streams studies in detail, comparisons of riverine flood determinations provided in the most recent reports with those of this study are summarized as follows:

Waipa Stream and Waiolo Stream—The present study has flood elevations and floodplain boundaries similar to those furnished by the FIS for the Hanalei area (HUD, 1972).

Hanalei River—The present study gives higher flood elevations than, but similar flood plain boundaries to, those given in the FIS for the Hanalei area (HUD, 1972).

Anahola Stream—The present study provides flood elevations and floodplain boundaries similar to those given in the FIS for the Anahola area (HUD, 1972).

Moikeha and Waikaea Canals—The present study shows smaller floodplains than those delineated by the USACE flood hazard area report on the canals (USACE, 1974).

Wailua River—The present study has somewhat lower flood elevations than, but floodplain boundaries similar to, those provided in the FIS for the Wailua area (HUD, 1972).

Opaekaa Stream—The present study has lower flood elevations immediately upstream of Kamulu Road, but floodplain boundaries similar to, those provided in the USACE flood hazard area report on the Opaekaa area (USACE, 1973).

Nawiliwili Stream—In the Nawiliwili area, the present study shows flood elevations and floodplain boundaries similar to those given in the FIS for the Niumalu-Nawiliwili area (HUD, 1973). In the Lihue area, the present study shows a slightly smaller flood plain than that delineated on the USACE flood hazard area report (USACE, 1975).

Puali Stream—The present study has flood elevations and floodplain boundaries similar to those presented in the FIS for the Niumalu-Nawiliwili area (HUD, 1973).

Waikomo Stream, including the lower reaches of Omao Stream and Waihohonu Stream—The present study shows a much smaller floodplain for these streams than that delineated by the FIS for the Koloa-Poipu vicinity (HUD, 1973).

Hanapepe River—The present study gives slightly higher flood elevations than, but floodplain boundaries similar to, those provided in the FIS for the Hanapepe area (HUD, 1972).

Comparisons of the flood elevations and floodplain boundaries determined in this study with those of other studies for the streams and coastal areas studied in detail are summarized below:

Wainiha River—This study has floodplain boundaries that are very similar to those of the approximate study made for the May 1981 FIS (FEMA, 1981). The delineation of the 1-percent annual chance coastal flood elevations was revised slightly and the delineation for the 0.2-percent annual chance coastal flood was added for this study. A comparison was made also with the Wainiha flood hazard area report (USACE, 1975). The riverine flood elevations in the downstream reach are lower for this study; the upstream flood boundaries are similar.

Waimea River—This study has similar riverine flood boundaries as the approximate study made for the May 1981 FIS (FEMA, 1981). However, the boundary for the interior flooding has been revised in this report. The delineation for the 0.2-percent annual chance flood was also added.

8.0 LOCATION OF DATA

Information concerning the pertinent data used in the preparation of this study can be obtained by contacting the Mitigation Division, Federal Emergency Management Agency, 1111 Broadway, Suite 1200, Oakland, CA 94607

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